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THE BAROSSA ARCHED CONCRETE DAM IN SOUTH AUSTRALIA.

By Alex. B. Moncrieff,* M. Am. Soc. C. E., M. Inst. C. E.

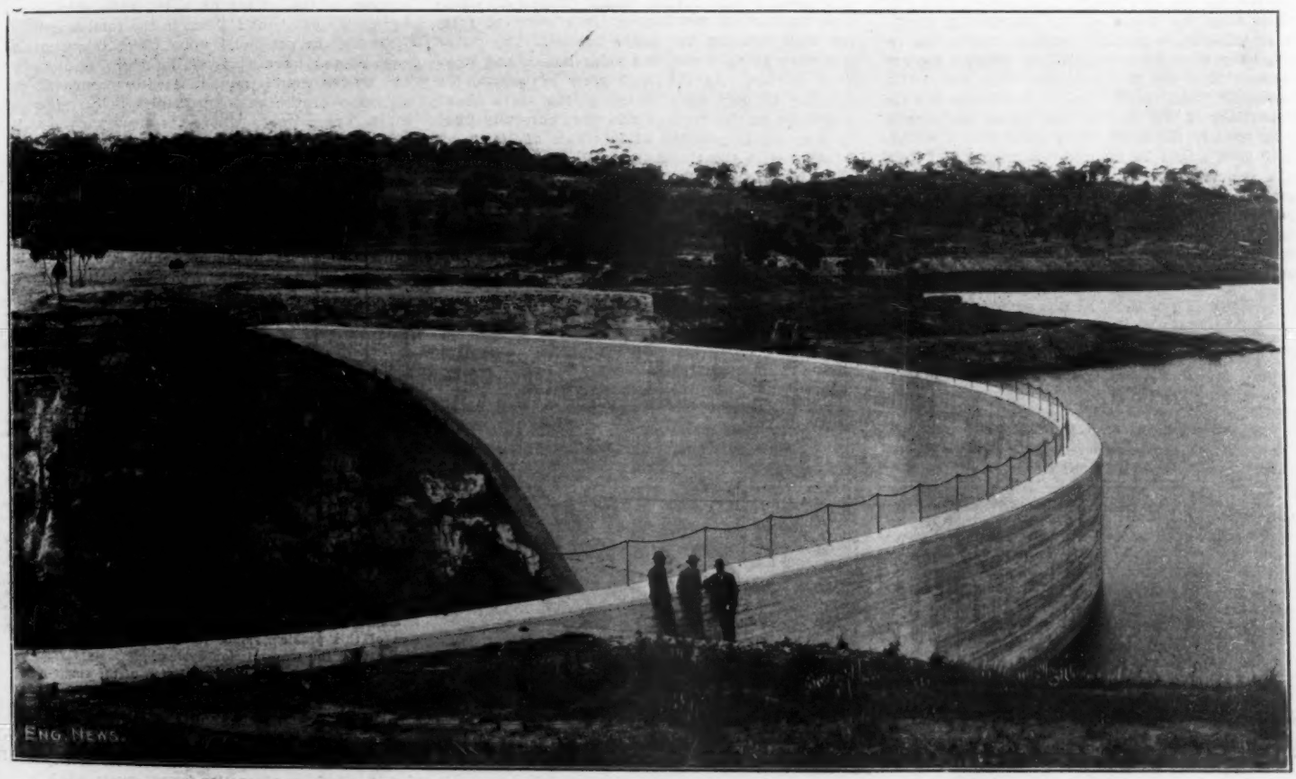
The accompanying photographs illustrate the highest arched concrete dam in Australia, which has recently been completed by the South Australian Government at Barossa, near Gawler. The top of the dam is 94 ft. above the ground line, and it is only 4 ft. 6 ins. wide at the top. The greatest thickness of concrete above the line of foundation is 34 ft. at the ground line. The dam is an arch with a radius of 200 ft. and the total length of the arc of the circle formed by the top of the dam is 472 ft.

*Engineer-in-Chief, South Australian Government, Adelaide, Australia.

The Barossa Water-works were constructed for the supply of the town of Gawler, South Australia, and the surrounding farming district, the water to be delivered in cast-iron pipes under pressure for domestic purposes and stock, with a small surplus for garden irrigation, the supply being estimated at 1,000 million gallons per annum. The total expenditure approved by Parliament in November, 1898, for the original scheme was £225,000. The work was commenced in March, 1899, and was completed in February, 1903, at a cost of £169,947—the saving on the original estimate being due to the substitution of an arched concrete dam for a structure of gravity type, as originally proposed.

The original scheme included a concrete weir across the Para River, from which, when the dirty floods have passed, water is taken through a tunnel into a storage basin having a capacity of 1,000 million gallons. The tunnel is 7,400 ft. long, about 7 ft. 6 ins. in diameter, and lined with concrete for about half its length. The storage basin is protected against impure drainage by an intercepting channel 1¼ miles in length, and is provided with outlet works, there being a main 22 ins. and 18 ins. in diameter, and about 7 miles long to the town of Gawler, the said main being constructed of steel on the locking-bar principle, already illustrated in the columns of Engineering News (Dec. 29, 1898).

The chief interest of the works lies in two particulars, viz., that the supply from the intermittently flowing river is under complete control by means of cast-iron doors at the entrance to the tunnel, dirty flood waters being rigorously excluded, and that the large storage is behind the



ARCHED CONCRETE DAM AT BAROSSA, SOUTH AUSTRALIA.
Alex. B. Moncrieff, M. Am. Soc. C. E., M. Inst. C. E., Chief Engineer.

arched concrete dam of the unusual dimensions given above.

The dam is situated in a narrow valley with a steep rock cliff about 100 ft. in height on one side and a gently sloping spur of the range on the other. The accompanying cross-sections and plan of the dam show the general dimensions and quantities.

The foundations throughout were carried down to solid rock, and the excavation was carefully stepped for the reception of the thrust of the arch into the hill on both sides. The utmost care was taken that the whole of the ingredients should be as uniform as possible, and, to insure this result, they were all dealt with by weight, the appliances used for this purpose being automatic. Numerous tests were made before determining the proportions of the various aggregates and cement to be used in the concrete in order that a watertight dam might be insured. A number of 2-ft. cube concrete blocks were manufactured with varying proportions of ingredients, placed under hydrostatic pressure of 200 ft., and proved impervious before the proportions of the material to be used in the concrete were finally determined. The sand and stone were carefully washed and the cement was aerated for 14 days before using. The quantity of cement necessary to produce half a cubic yard of concrete was then mixed with the required proportions of sand in two operations and tipped in layers between the various charges of aggregate to assist in thorough incorporation. The combined aggregates, sand and cement, were then passed through a Messent concrete mixer and immediately placed in the work, the courses being so proportioned as to thoroughly bond with the concrete above and below and also to break joint horizontally and vertically. Rubble displacers or "plums" of gneiss rock were placed in the concrete, the rule observed being that no large stone should be nearer to any other than 6 ins.

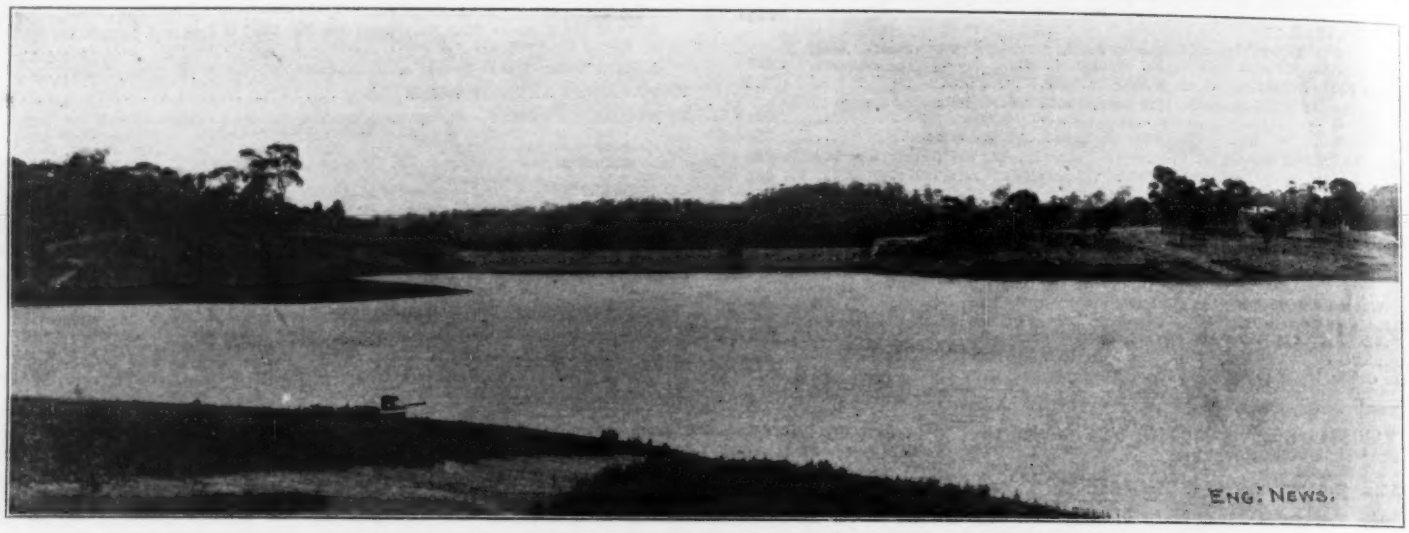
When the general level of the concrete had risen nearly to the natural surface of the gravel molding timbers were introduced, which were hung on bolts built into the wall at every 4 ft. vertical. Previous to insertion, these bolts were covered with paper from the cement casks and tied around with cotton, which formed an effective method of facilitating their removal from the wall, leaving the paper behind. The paper was then scraped out, the holes hosed, and filled with mortar. As the wall grew in height, the molding timbers were raised to the bolts above and those on the vertical side were carefully fixed in the correct position at intervals of 10 ft. by sighting with the theodolite. When within 15 ft. of the top of the wall, the use of the large "plums" was discontinued on account of the narrow width, and string courses of iron tramrails were built in horizontally, about 40 tons being so used. The work of concreting was commenced in August, 1900, and completed in September, 1902, or at the rate of about 30 cu. yds. of concrete and 5 cu. yds. of displacers per diem, which was considered sufficient for uniformity in the setting of the mass.

Upon completion, the cubic contents of the work were carefully measured and agreed with the figures arrived at by weighing in. The cost of the rubble concrete was 38s. 9d. ($9.30) per cu. yd.

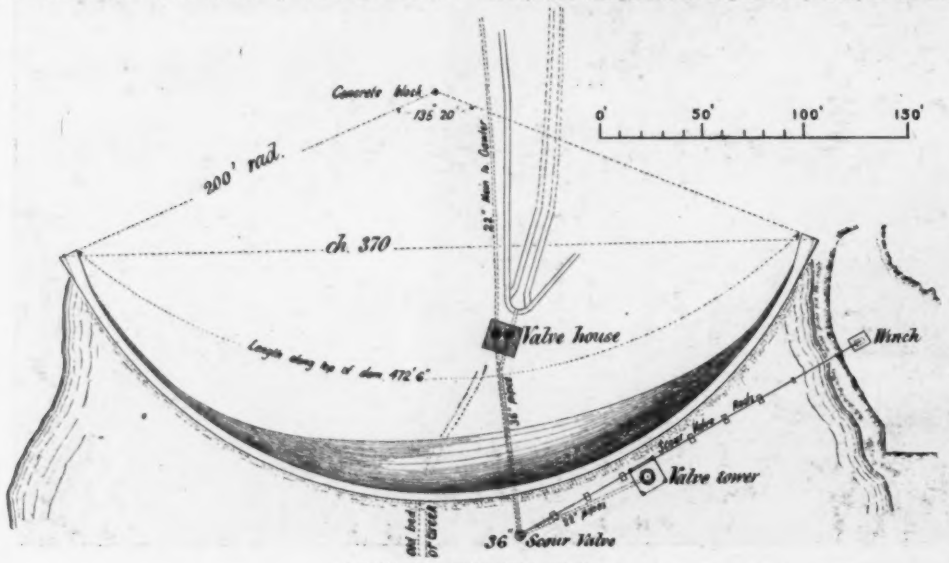
Instructions were given that the water should be allowed to rise in the basin of the reservoir as the work proceeded, and this was done as far as possible, but the final filling of the reservoir did not take place until September, 1903. The atmospheric temperature during construction of the dam ranged between 30° and 168° F. In frosty weather the concrete was covered with straw mattresses, and a number of small smoking fires in tar drums were burnt at intervals on staging along the top of the wall with beneficial effects.

Since completion, and from observations made during six days upon which equal extremes of temperatures amounting to 50° prevailed, the top of the wall at the crown was found to tilt upstream to the extent of 7/8-in., thus showing an expansion of about 1½ ins. in the total length.

So far, the principles upon which this dam was constructed have given satisfactory results, and the writer would not hesitate to recommend the adoption of the same principles in carrying out much larger works where the situation was suitable and where proper materials were obtainable. The construction, especially of the upper or thinner part of the dam during the winter season and the insertion of steel bars therein, I look upon as advisable, and am decidedly of the opinion that a properly constructed concrete work, all the materials of which are practically of the same specific gravity, is better than a composite structure consisting partly of masonry and partly of concrete.



A VIEW OF THE BAROSSA RESERVOIR LOOKING TOWARD THE DAM.



PLAN OF BAROSSA DAM.

SINGLE-PHASE RAILWAYS.*

By W. A. Blanck.†

In perhaps no line of electrical industry has there been greater activity than in that of interurban railway construction, until at the present time throughout the United States (and particularly in the Central States) this development has reached a magnitude entirely beyond the expectation of the most sanguine of a decade since. There are many cases in which an electric railway would be of doubtful value to the owners with the present direct-current system, involving the use of rotary converter substation and low trolley voltage, but would be very profitable in case a system can be developed which will materially reduce the cost per mile. For some time the perfection of a single phase motor has been suggested as the solution of this problem, since it allows great reduction in the cost of the transmission system.

The present activity in the evolution of the single-phase railway motor gives added interest to the problem, and there is a marked decrease in the cost of a typical line with high-voltage trolley and static transformer stations in the single-phase railway system. The first vital question which arises in this connection is the development of a single-phase alternating-current motor which will operate satisfactorily under the conditions imposed by railway service, and a short account of the present state of the art will not be out of place.

SYNCHRONOUS MOTOR.—Since the synchronous motor requires a separately excited field, has no starting torque and cannot be run at variable speed, its direct application in railway traction is impossible. It has, therefore, been proposed by Ward Leonard to use the synchronous motor in combination with a direct-current

*Abstract of a paper read before the local chapters of the American Institute of Electrical Engineers at Cincinnati, O., and Chicago, Ill., in February and March, 1904.

†Arnold Electric Power Station Co., Marquette Bldg., Chicago, Ill.

generator, the latter to furnish direct current to the standard axle motors.

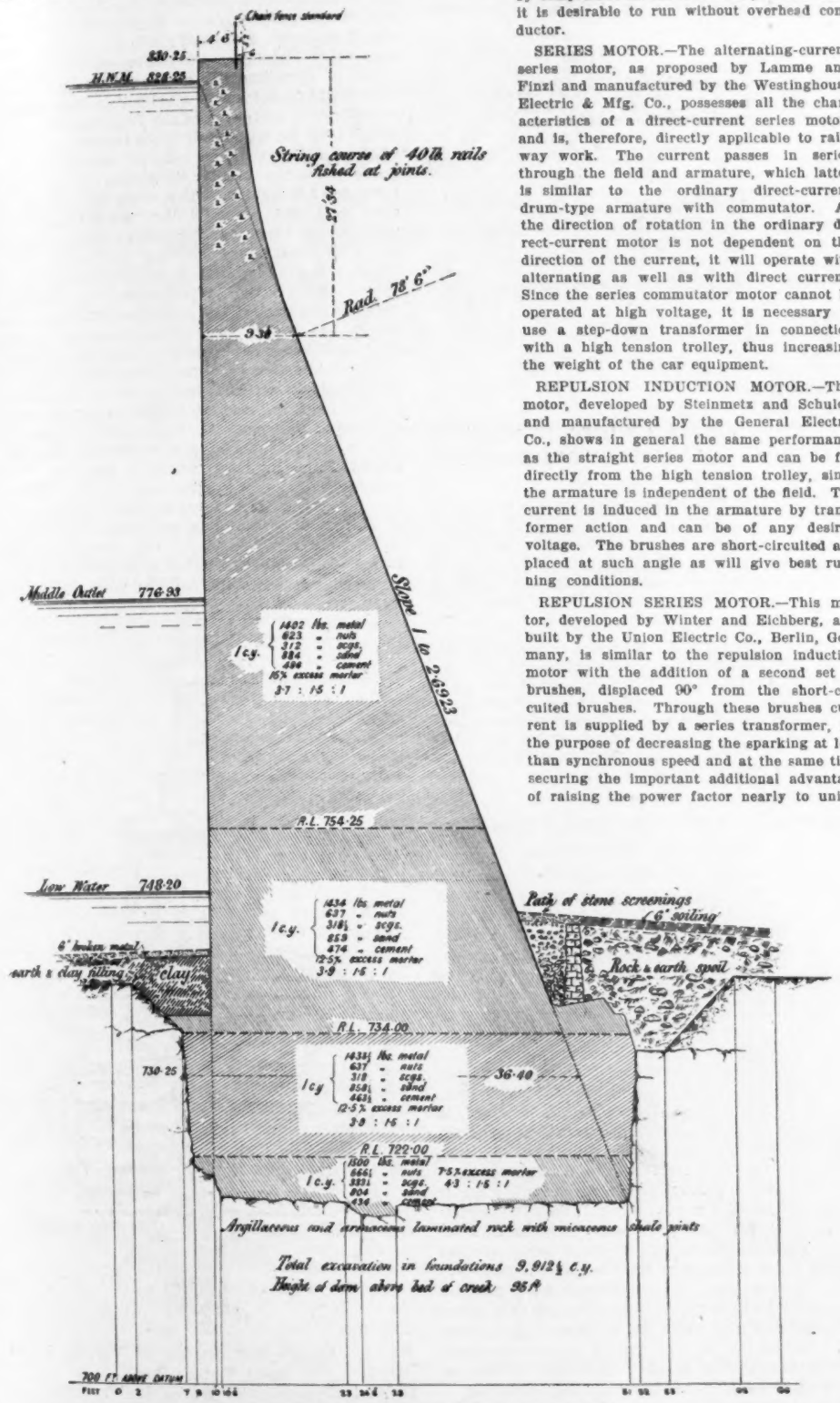
INDUCTION MOTOR.—The induction motor shows the same peculiarities in respect to starting and speed control as the synchronous motor, but to overcome these Mr. Bion J. Arnold proposes a suitable combination of the induction motor with a mechanical storage battery, consisting of an air compressor and tank (Engineering News, Jan. 7, 1904). In this system both parts of the motor are free to rotate and maintain a constant relative speed. The rotor is geared to the axle and also connected to one air cylinder. The stator is connected to a second air cylinder, in which air is being compressed, when the car is running at less than full speed. With the car running at full speed the stator is at rest and no compression work done. By admitting air to the cylinder and rotating the stator in the same direction as the rotor the car can be run with over synchronous speed.

This combination, with the induction motor continually running, makes it possible to store energy when the car is coasting or stopped and to utilize this energy during acceleration. This system allows the operation of the car by compressed air for a limited period in case it is desirable to run without overhead conductor.

SERIES MOTOR.—The alternating-current series motor, as proposed by Lamme and Finzi and manufactured by the Westinghouse Electric & Mfg. Co., possesses all the characteristics of a direct-current series motor, and is, therefore, directly applicable to railway work. The current passes in series through the field and armature, which latter is similar to the ordinary direct-current drum-type armature with commutator. As the direction of rotation in the ordinary direct-current motor is not dependent on the direction of the current, it will operate with alternating as well as with direct current. Since the series commutator motor cannot be operated at high voltage, it is necessary to use a step-down transformer in connection with a high tension trolley, thus increasing the weight of the car equipment.

REPULSION INDUCTION MOTOR.—This motor, developed by Steinmetz and Schuler, and manufactured by the General Electric Co., shows in general the same performance as the straight series motor and can be fed directly from the high tension trolley, since the armature is independent of the field. The current is induced in the armature by transformer action and can be of any desired voltage. The brushes are short-circuited and placed at such angle as will give best running conditions.

REPULSION SERIES MOTOR.—This motor, developed by Winter and Eichberg, and built by the Union Electric Co., Berlin, Germany, is similar to the repulsion induction motor with the addition of a second set of brushes, displaced 90° from the short-circuited brushes. Through these brushes current is supplied by a series transformer, for the purpose of decreasing the sparking at less than synchronous speed and at the same time securing the important additional advantage of raising the power factor nearly to unity.


Chain fence standard
4' 6"
830·25
H.W.M. 828·25
String course of 40lb. rails flshed at joints.
27'34
Rad. 78' 6"
9·36
Middle Outlet 776·93
1 c.y. 1402 lbs. metal, 623 " nuts, 312 " scgs., 884 " sand, 494 " cement, 15% excess mortar, 3·7 : 1·5 : 1
Slope 1 to 2·6923
R.L. 754·25
Low Water 748·20
1 c.y. 1434 lbs. metal, 637 " nuts, 318½ " scgs., 859 " sand, 474 " cement, 12·5% excess mortar, 3·9 : 1·5 : 1
Path of stone screenings 6" soiling
6" broken metal
earth & clay filling
Clay
Rock & earth spoil
R.L. 734·00
730·25
1 c.y. 1433½ lbs. metal, 637 " nuts, 318 " scgs., 858½ " sand, 463½ " cement, 12·5 % excess mortar, 3·9 : 1·5 : 1
36·40
R.L. 722·00
1 c.y. 1300 lbs. metal, 666½ " nuts, 333½ " scgs., 804 " sand, 434 " cement, 75% excess mortar, 4·3 : 1·5 : 1
Argillaceous and arenaceous laminated rock with micaceous shale joints
Total excavation in foundations 9,912½ c.y.
Height of dam above bed of creek 98 ft
100 FT ABOVE DATUM
FEET 0 2 7 8 10 16 33 36 38 51 52 63 66 68

CROSS-SECTION AT CENTER OF BAROSSA DAM.

DESCRIPTION OF CONCRETE USED.

Aggregate { Metal through 2-in. and caught on 1¼-in. ring—4½-in. parts; Nuts " 1¼-in." " " ½-in. " —2-in. "; Screen'gs " ½-in." " " ⅛-in. " —1-in. " } Specific gravity 2.45, about 35% voids.

Mortar... { Alsen's Portland cement, 1 part. Sand, ½ from River Para, ½ rock breaker—1½ parts.

These ingredients weighed and the amount of each necessary to produce 1 cu. yd. is shown on section; also the percentage of mortar allowed in excess of voids in aggregate. The average concrete (including mortar for bedding plums) was 3.5:1.5:1.

FINAL QUANTITIES (Dam and Foundation).

17,975 cu. yds. rubble concrete..... { 15,760 cu. yds. cement concrete, 2,215 " " rubble displacers (plums).

CONTROLLERS.—In general the operation of the last three motor systems is effected by master controllers operating suitable contactors to get the desired combinations. Induction regulators are used in all three cases to secure the voltage variation necessary for speed control, thus avoiding the losses consequent to the rheostatic control of the direct-current system.

CAR WIRING.—In order to protect passengers and crew form the high potential used in this system, it is necessary that the wiring should be done in metallic conduit; this should be connected to the trucks so that any defect in the insulation of the circuit will result in the tripping of the automatic circuit breaker in the car. Moreover, it will be necessary to insulate the steps and hand-rails to guard the passengers from shocks, which might result from wet weather or the car standing on a dirty rail.

TROLLEY BOW.—With the high-tension working conductor it is necessary to provide against any possible short-circuiting of the trolley and its suspensions. On account of the serious results which would follow the slipping of the trolley pole so common in the present system, a suitable bow must be used instead. The bow should be of such length that no manipulation will be necessary in reversing the car. This trolley bow is mounted on a well insulated platform on the roof of the car, which also supports the springs necessary to maintain the requisite pressure between the bow and the trolley wire. A small air cylinder, mounted on the same platform, operated by compressed air from the brake system, should be so connected as to lay the bow flat on the roof of the car in case the necessity arises to temporarily disconnect the bow from the trolley.

The contact part of the bow can be made either of soft copper or aluminum and the necessary lubrication is accomplished by grease applied in a slot extending the length of the bow. The bow trolley in use on the Valtellina railway in northern Italy, with a working pressure of 3,000 volts, consists of copper cylinders rolling in insulated ball bearings. Brushes take the current from these revolving cylinders to the steel tubes carrying the contact piece.

TROLLEY LINE CONSTRUCTION.—Great care must be given to the construction of the high-tension trolley line in order to avoid damage to life and property. Notwithstanding the prevalent idea that the danger of these high-tension trolleys will handicap the development of alternating-current railways operated over public property, there is no reason why they should not be made as safe as the high-tension distributing systems of lighting companies, now so common on public property. It is of the first importance to provide such a hanger as will readily withstand the working pressure of the system and can be easily replaced in case of mechanical or electrical defect.

In the trolley line construction on the Valtellina railway, the bolt carrying the trolley clamp is surrounded by an insulating compound, called ambroin, and set into a malleable iron bell provided with clamp arms to secure it to the span wire. A cast-iron cap screw holds the insulated bolt firmly in place. In the construction used on the Lansing, St. Johns & St. Louis Ry., in Michigan (Engineering News, Jan. 7), the hanger consists of a special high-tension glass insulator fastened to the span wire in the usual way. The working conductor is carried by an iron pin inserted in a wooden sleeve on which a thread is turned to fit the glass of the insulator. A thin lead bushing allows the insulator to be firmly clamped by the malleable iron supports, thus preventing the hanger from jarring loose.

If the road passes along a public highway, special precautions should be taken to avoid accident. In one system the working conductor is suspended at intervals of about 10 ft. from two steel wires, forming, with the bracket arm, an inverted triangle. In case of mechanical break in the trolley wire it is evident that the end cannot reach the ground or injure passers by. It might be noted in passing that this construction increases the carrying capacity of the trolley with but slightly greater investment. A construction somewhat similar to this is in use on the single-phase railroad near Berlin.

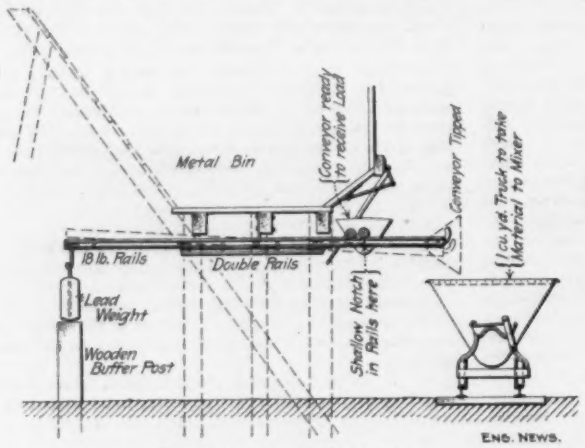
In regard to rail return, it may be said that with the proposed frequency of 25 cycles per second and the small current required with the higher voltage this portion of loss will be even smaller than in direct-current work, so that for normal interurban service it will be sufficient to bond only one rail. This has the advantage (greatly to be desired in many cases) of leaving the other rail free for the purpose of block signal connections. Furthermore, the evils of electrolysis are completely avoided with the alternating current system.

In order to consider more in detail the relative merits of the alternating-current and direct-current systems of distribution, a comparison may be made for a 60-mile single-track interurban railway. We will assume the power house to be located at the center of the line and to contain one substation, and that the four remaining substations are located at equal intervals on the line. Although the alternating-current system would not require substations at so frequent intervals, they are retained on account of the advantage to be derived from the sectionalizing of the line and the more advantageous distribution of power due to the larger number of feeding points. The

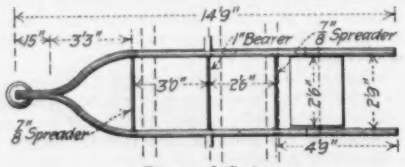
schedule proposed consists of five local cars having one hour headway; one express car, making the round trip in three hours, and one freight and baggage car making the trip between the two terminals in about eight hours. The average power required by the various cars will be as follows:

	Weight in tons.	Schedule speed m. p. h.	Watt-hrs. per ton mile.	KW.-hrs. per trip.	Average power Kilowatts.
Local car....	30	25	80	144	60
Express car..	35	42.8	110	231	105
Freight car...	30	12.5	70	126	25

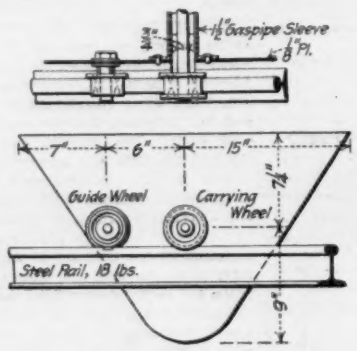
With the schedule outlined above, the average load on all five substations will be about 500 KW., or 100 KW. per substation, while the maximum load per substation under certain conditions is 450 KW., as when the express car is starting and two locals are running in one section. With a proper momentary overload allowance this assumed condition will require one 300-KW. rotary converter per substation, to be installed in the direct-current system. In the alternating-current system, however, a static transformer of 200 KW. capacity per substation will be ample. The maximum load at the power house will be 800 KW., and two 400-KW. units will suffice, if for the purpose of this comparative study no reserve capacity be provided either in power house or substations.



Elevation of Balance.



Plan of Balance.



Details of Balance.

APPARATUS USED IN WEIGHING CONCRETE INGREDIENTS FOR BAROSSA DAM.

(The measuring conveyor is balanced to run on the wheels A and is run back until they drop into a shallow notch on the rails. The door of the metal bin is then opened and the box allowed to fill until the lead weight commences to rise when it may be pushed into the position shown for tipping, being aided by gravity.)

As to the motor equipment in the two systems, at present the alternating-current motor weighs somewhat more than the direct-current motor and operates at a slightly lower efficiency. However, the smaller efficiency of the alternating-current motor is more than counterbalanced by the small percentage loss in the alternating-current distributing system. And, with the rapid development now taking place in this motor, it is safe to assume that in the very near future its characteristics as to weight and efficiency will equal those of the direct-current motor, thus making the advantage of the alternating current railway system still more evident. An idea of the relative investments for the two systems may be best obtained by comparing the cost of the various items:

	Direct current.	Alternating current.
Power house and plant	$103,000	$106,500
Substation at power house	12,600	4,600
Transmission line (48 miles)	22,500	20,500
Substations and plants (4)	54,000	28,000
Trolley line and feeders	156,000	78,000
Bonding rails	32,000	16,000
Rolling stock	110,000	126,000
Total	$490,100	$371,600
Cost per mile	8,169	6,193

Difference in favor of alternating-current, per mile, $1,955.

It is not necessary to take up in detail all the items, as they speak for themselves, but it may be of interest to note some items in which the costs vary more widely. The single-phase generators, as would be expected, cost nearly 30% more than three-phase generators, the extra cost amounting to $5,000. Small savings on switchboard and wiring reduce the total for the power house $3,500 in favor of the direct-current system. For the substation in the power house, principally on account of saving in converter and transformer capacity, the balance is $8,000 in favor of the alternating-current system. The transmission systems are approximately the same, there being $2,000 in favor of the alternating-current system.

In the alternating-current distributing system, while the suspension of the trolley is noticeable more expensive than in the direct-current system, on account of special insulators, the immense saving in copper gives a balance of $78,000 in favor of the alternating current system (trolley wire, $95,000 for direct-current and $21,500 for alternating-current). The necessity of bonding but one rail effects a saving of $16,000 in favor of the alternating-current system. A very liberal allowance has been made by placing the cost of the alternating-current motor equipments one-third higher than that of the direct-current motor equipment; this, as above noted, is the present cost of alternating-current equipment, and without doubt in the near future this difference will be greatly reduced.

The total saving by the use of the alternating-current system is $1,955 per mile. Expressed in percentage this means that the alternating-current system effects a saving of 25% of the cost of the direct-current system; or, to state the relation in other words, the cost of the direct-current system is 32% more than the cost of the alternating-current system, a showing most favorable for the latter, and this indeed during the first year that this apparatus has been on the market.

HIGH-PRESSURE MULTI-STAGE TURBINE PUMPS WITH SPECIAL BALANCING DEVICE.

To apply electric motors to the work of pumping, rotary or "centrifugal" forms of pump are almost essential. The objection to the conventional style of centrifugal pump for most classes of pumping service is its unsuitability for working against even moderately high pressure. Moreover, even at the most favorable pressure for a given pump of this kind, its efficiency is not very great, possibly 60% as a maximum, falling off rapidly as the pressure increases or diminishes.

High efficiency in centrifugal or rotary pumps need not primarily be considered a desideratum. Ability to pump against high heads, however, is absolutely essential to any great extension of the field of usefulness of the rotary pump. This fact lent great value and interest to the introduction of a type of pump developed in a scientific manner from the principles governing turbine construction. European engineers were the pioneers in this. Turbine pumps of excellent design, suited for very high heads and giving satisfactory efficiency, have been built in Europe for a number of years.* More recently, American pump builders have entered the same field. Some illustrations and data of the turbine pumps of one American maker, the Byron Jackson Machine Works, of San Francisco, Cal., are given in the following.

It is to be noted that centrifugal pumps of the ordinary kind have in some cases been adapted to heads higher than a single pump could serve, by coupling them in series, so that each pump worked against only a part of the total delivery head. Essentially the same thing must usually be done with turbine pumps, with the difference that in this case each separate pump or "stage" is able to pump against five to ten times the limiting head of the ordinary centrifugal pump. This difference is wholly due to careful design of the impeller blades and the addition of guide passages (like those in turbines) for the purpose of converting velocity into pressure with minimum eddy losses. The pumps shown and described in the following are multi-stage turbine pumps of this kind.

*See a description of a four-stage turbine pump built by the Swiss firm of Sulzer Bros., in Eng. News of Jan. 23, 1902.

The operating elements of the Jackson pumps are rotating impellers containing spirally curved water passages, and fixed guide passages between successive impellers. The water enters the passages of each impeller at the center and by the rotation is forced out to a collecting chamber surrounding the periphery of the impeller. The ducts which lead the water from here back to the center of the next impeller are suitably curved to act as guide passages, similar in action to the guide buckets of a turbine. The water then enters the next impeller in an axial direction, its rotary motion having been transformed by the guide passages into rectilinear motion.

Fig. 1, a drawing of a vertical pump in section, shows the relative arrangement of impellers (marked A) and guide passages (B). The pump shown has the suction entrance at the top; the discharge leaves the collecting chamber of the last (lowest) impeller in a tangential direction. The shaft rests in a thrust bearing at the top, and is further held by bearings formed in the successive sections of the case. At the bottom it is provided with a special balancing arrangement, described below. Each impeller, where it joins the guide passages of the preceding case section, is fitted into the case so as to form as tight a joint as possible without introducing any great frictional resistance to rotation. With the exception of the entrance opening, the external surface of the impeller is exposed to the delivery pressure, so that

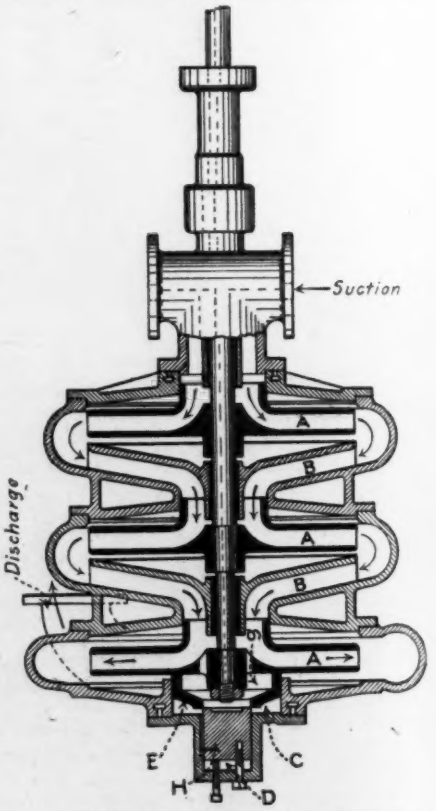


Fig. 1. Longitudinal Section of Vertical Three-Stage Turbine Pump.
Byron Jackson Machine Works, San Francisco, Cal., Builders.

there is a resultant upward pressure on each impeller, equal to the area of its entrance multiplied by the difference between the entrance and discharge pressures of that stage. If all the impellers are alike, the total upward thrust is equal to the product of entrance area multiplied by the total head on the pump. The pumps are so proportioned that this upward thrust slightly exceeds

the weight of the rotating portion, consisting of impellers and shaft. The excess of upward pressure, however, is relieved by the balancing device located at the lower end of the shaft, with the result that the rotating part is precisely balanced, thus relieving the thrust bearing of all load while the pump is running.

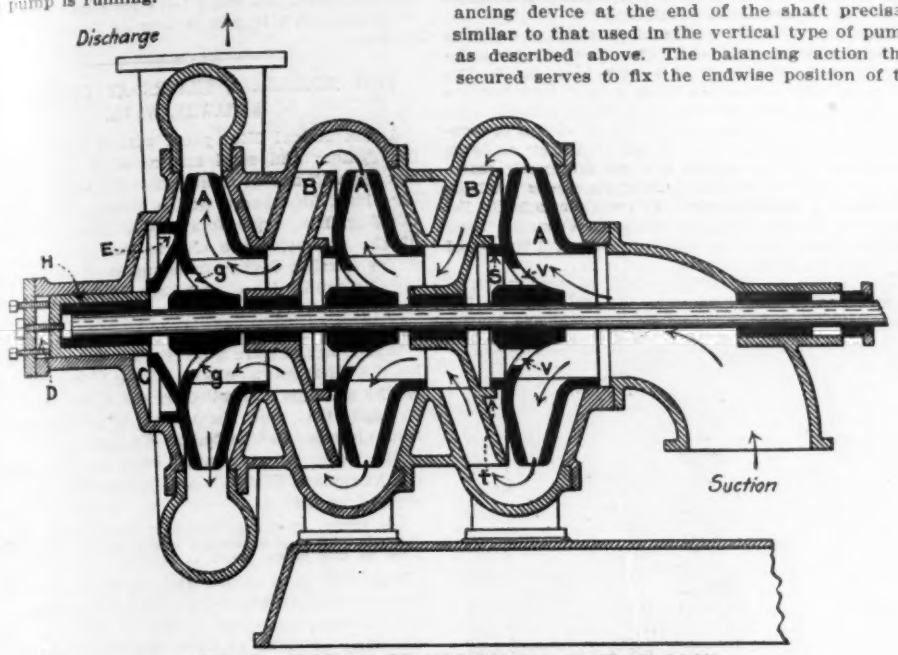


FIG. 2. SECTION OF HORIZONTAL TURBINE PUMP.

The balancing device referred to consists of two chambers, C and D, formed centrally in the bottom of the lowest section of the pump case. The large chamber, C, encloses a projecting hub, E, on the lower surface of the impeller. This hub of course rotates with the impeller, and the joint between the hub and the walls of the chamber is, therefore, loose enough to allow water from the delivery side of the last impeller to leak into chamber C and establish the full discharge pressure in that chamber. The small lower chamber, D, contains a plug H, which may be adjusted endways by means of screws. The forward end of this plug fits closely into a recess in the face of the hub, E, which recess communicates, by way of the hollow central part of the hub and the passages g, with the entrance side of the last impeller. The action of the device is as follows: When chamber C becomes filled with water, or rather when leakage through the joint around the hub E has raised the pressure in the chamber C to the delivery pressure, the total upward pressure on the impellers is greater than the total weight of the rotating part of the pump. The rotating element is therefore lifted until the recess in hub E is raised clear of the plug H. In this position the pressure in chamber C is relieved through the passages g, with the result that the rotating element again settles down over the adjusting plug H. As this action tends to recur, a position of equilibrium is established near the point where the plug just enters the recess in the hub E. The precise position of this point may be altered by the adjusting screws of the plug H, thereby adjusting the endwise position of the impellers in the casing. When the pump is not in operation, of course the upward pressure of the water does not act, and the weight of the rotating part must be carried by the thrust bearing.

When these pumps are built with horizontal shaft, the unbalanced pressure which is thus turned to account in the vertical pump becomes harmful and must be avoided. The arrangement by which this is accomplished is shown in Fig. 2, where the letters A and B designate respectively the impellers and the guide passages as before. The rear of each impeller, that is, the side opposite the entrance opening, bears a short annular projection, s, fitting within a similar ring, t, projecting from the casing. The circular chamber formed by these two rings communicates, through holes, v, in the web of the impeller, with the entrance side of the impeller. The chamber being slightly larger than the entrance opening of the impeller, it serves to eliminate all thrust on the impeller in the direction of the suction (since the remainder of the external surface is exposed to the discharge pressure), and produces instead a small thrust directed toward the discharge end. This small resultant thrust is taken up by a balancing device at the end of the shaft precisely similar to that used in the vertical type of pump, as described above. The balancing action thus secured serves to fix the endwise position of the rotating part; moreover, it affords sufficient margin to compensate for longitudinal thrusts which may result from causes such as slightly non-central position of the impellers in their casing.

Pumps of this design are built for heads of from 100 to 2,000 ft., the number of separate impellers or "stages" being properly proportioned to the head. About 100 to 250 ft. head per stage appears to be allowed. A high efficiency of working, from 70 to 80%, is said to be realized.

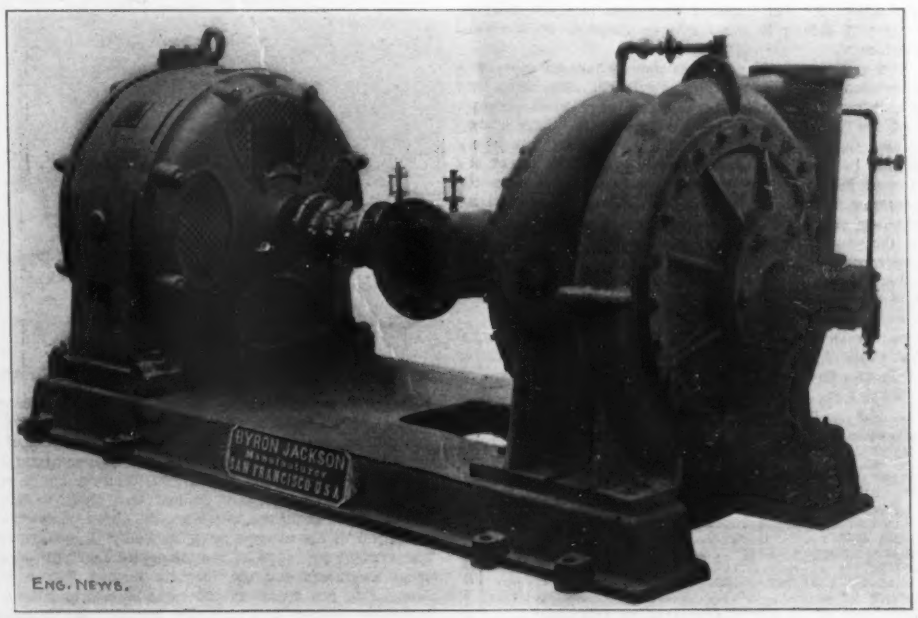


FIG. 3. HORIZONTAL TWO-STAGE TURBINE PUMP DIRECT-CONNECTED TO INDUCTION MOTOR.

The horizontal two-stage pump shown in Fig. 3 is one built for the water-works of the city of Stockton, Cal., for delivering 1,500 gallons per minute against a head of 140 ft., at 690 r. p. m. It is driven by a 75-HP. induction motor of the Westinghouse Electric & Mfg. Co., of Pittsburg, Pa. Pump and motor are mounted on a common base, and their shafts are solidly coupled. This pump was guaranteed to have an efficiency of at least 75%, but we are informed by the manufacturers that the official test showed it to have an efficiency of 82%.

A vertical pump of four stages is shown in Fig. 4. It has a discharge capacity of 450 gallons per minute, and delivers against a head of 500 ft. The same type of pump, however, can work against heads up to 800 ft. The mounting of the pump in the present instance is at the bottom of a 200-ft. pit; the pump shaft leads vertically to the surface, where it is driven by belt. This pump was built for the Rubio Canon (Cal.) Water Co. A closely similar installation has been made for the city water-works of New Albany, Ind., where two vertical three-stage pumps operate under a head of 310 ft. The pumps are located in a 30-ft. pit, and their shafts are extended to the surface, where they carry each a 200-HP. induction motor mounted directly on the shaft. The balancing action of the pump was in this case designed to be sufficient to carry the entire weight of the rotating part, that is, rotor, shaft and pump impellers.

THE OPPORTUNITIES IN THE ELECTRICAL BUSINESS.

By George A. Damon.†

(The author recently sent a letter to 100 prominent young men in Chicago engaged in various branches of the electrical industry, inquiring concerning their age, education and rate of salary, with a view to ascertain by the actual experience of men in the electrical business what were the prospects of a youth engaging in this field of work. As young men are in control in the electrical business, the inquiry was confined to men between the ages of 27 and 45. The following is an analysis of the results of the inquiry as presented by Mr. Damon.)

An effort was made to make the list representative, and the men were selected on account of their positions without reference to their incomes. It is to be understood that the dollar is not the most desirable standard by which to measure men individually, but looked upon as a class, a study of the averages furnished by the inquiry is interesting and may be made instructive. The hundred men may be divided into the groups given in the table at the top of the following column.

Salesmen who have technical ability or possess engineering information, as a rule, get better salaries than those who do not. Add initiative and executive ability to the salesman's ability and he becomes a sales manager with a still greater reward. Enterprise and energy put the man in possession of his own business, or often result in a partnership arrangement. A technical man without the commercial instinct is only fairly well paid. Ability to develop new methods or apparatus puts him in the expert class where the rewards are greater and in proportion to his ability. Routine work, such as operating, is the least remunerative work of all. Operating man-

*Abstract of a paper read before the Electrical Section of the Western Society of Engineers, Chicago, on March 18.

†Managing Engineer, Arnold Electric Power Station Co., Chicago.

	No. of men.	Average age.	Average income.
Salesmen	7	33	$2,400
Sales managers	11	36	3,400
Business men	10	36	4,800
Sales engineers	8	35	2,350
Electrical engineers	16	33	2,800
Constructing Engineers	6	33	2,850
Electrical experts	8	33	3,200
Operating engineers	3	32	2,250
Operating managers and superintendents	10	34	3,350
Professors and editors	8	34	2,500
Patent attorneys	4	32	4,000
Consulting engineers	9	40	6,400

General averages: age, 33½ years; income, $3,440.

Classified in reference to incomes, the record is as follows:

	Men.
Income over $10,000 per year	5
Income between $5,000 and $10,000	9
Income between $2,400 and $5,000	66
Income below $2,400	20
Total	100

agers and superintendents, however, are very well paid. The editors were classed with the professors as there were too few to form a class with an average of their own.

The phenomenal development along all electrical lines, and particularly in the telephone business, makes the profession of patent attorney a paying one for those who are qualified for that kind of work. The field of consulting electrical engineering looks attractive, but it will be noted that the average age is greater in this branch than in the others, which means that the successful consulting engineer brings to his work years of experience, and that it is therefore not a branch to be adopted at once by the young man.

Of the men in the list, 40% are employed by what might be termed the "large" companies, such as the Western Electric, Chicago Edison, Chicago Telephone Co., etc.; 35% either control the business in which they are engaged or own a partnership interest; 25% are not college graduates; 20% never had any college education whatever.

The average age of the 20 men who are succeeding without a college education is 36 years, and their success measured by a monetary standard shows an income of $3,670 per year. The average age of 16 graduates of Cornell is also 36 years, and their success measured by the same questionable standard is $4,940, which shows a balance of $1,270 per year in favor of a college education. It will be noted, however, that the 20 men without the education are getting along financially slightly better than the general average of $3,440 per year. This is explained by the fact that in their number are included several men who are prospering as a result of their business enterprise.

There are few non-technical men engaged in the strictly technical end of the business who reach the average income. There seem to be more openings for the man without a college training in the telephone field than in any other. Of our hundred examples, 75% are married. Only 56% belong to the American Institute of Electrical Engineers.

The answers to the questions upon which an expression of opinion was asked resulted as follows: 80% think that a college education is essential to the highest success; 70% are in favor of the technical graduate taking a shop course in a large manufacturing company, but many wished to limit this course to one year; 55% are of the opinion that in choosing a life-work better chances for advancement will be found with the smaller companies; 70% are in favor of requiring a year's practical work of the student before graduation; 55% agree that the larger companies would be consulting the interest of the art at large by offering an apprentice course open to students during an intermission of one or two years before completing the senior year.

Each man included in the inquiry was asked to name the three fields which he considered most promising within the immediate future and the votes received are as follows:

Electric railway work	63
Telephony	36
Transmission	30
Electro-chemistry	29
Power applications	21
Lighting developments	12
Manufacturing	11
Central station work	9
Patent law	6
Consulting engineering	6
Contracting	5
Management of properties	5
Storage batteries	4
Reconstruction of plants	3
Mining	3
Metallurgy	3
Turbines	2
Wireless telegraphy, designing, high speed telegraphy, underground conduit construction, isolated plants, train lighting and municipal lighting, each	1

As a result of personal observation, tempered somewhat by the opinions of the electrical men, with whom the questions have been discussed, the writer wishes to present the following conclusions:

A COLLEGE EDUCATION.—A young man wishing to succeed in any branch of electrical industries makes a serious mistake if he fails to use every effort to obtain a technical education. A college course is becoming easier to obtain and it is already recognized as a general requirement for advancement. A young man of high aspirations, who is so situated that he cannot secure a university course, might better, nine times out of ten, take up some other branch of work which is less intricate than the electrical art. Nearly every man who is now making his way in the electrical business without a college training, if asked what he would do if he had his life to live over will say: "I would secure a technical course in the best college I could find."

CORRESPONDENCE SCHOOLS.—A technical course in a correspondence school which can give the proper training for an electrical engineer is yet to be produced. The correspondence schools are doing a good work and are to be recommended to those who cannot possibly avail themselves of a college course or get instruction in evening school, courses such as offered by Armour or Lewis Institutes, but a young man who will deliberately choose correspondence instruction if anything else is available is making a serious mistake. Of the 100 men in the list only two had completed a correspondence course. These two men were engaged in telephone work, and both voted in favor of a college course.

PRACTICAL EXPERIENCE.—Practical experience is as essential as theoretical training. Too little attention has been paid by students in getting into thorough contact

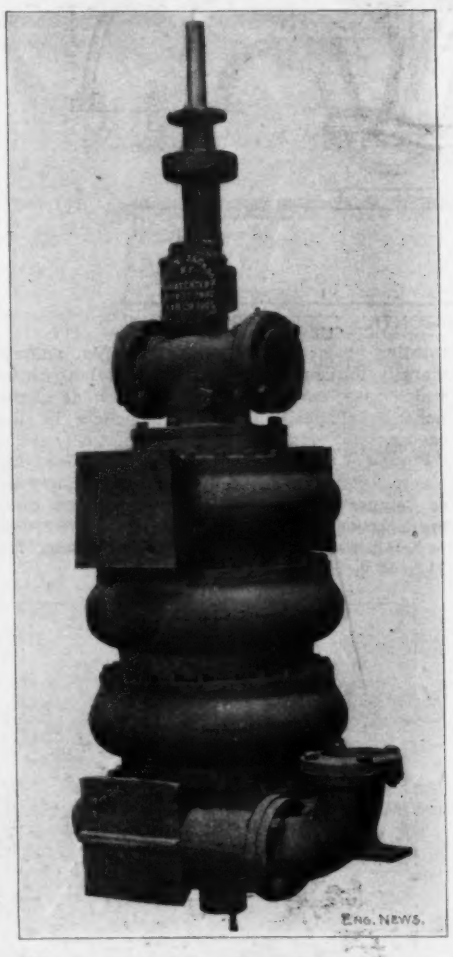


Fig. 4. Vertical Four-Stage Turbine Pump.

with the way things are actually done. This is the result of the general practice of allowing the young man to shift for himself. An association of thoroughly successful men should exercise some supervision over the preparation of the coming generation. If it is true that the art is suffering to-day from a lack of trained men ready to take up and solve the problems which are all about us, what must we expect of the morrow with its widening opportunities? The student branches of the American Institute of Electrical Engineers and the recently formed Edison Medal Association are moves in the right direction, but only a beginning toward realizing the possibilities. Considerable attention is being given to develop the best technical course, but a college training is less than half of an education. What constitutes the other half is a big problem waiting for a comprehensive answer.

SHOP COURSES.—The policy of the large companies in offering apprentice courses and opportunities for experience in their testing departments is to be commended. This practice, as carried on in some cases, however is to be criticised. A representative of a large manufacturing company visits a technical school, offering to give positions to all the members of the Senior class; the professor is highly complimented at this remarkable courtesy, and advises his students to accept. The "shop" course usually covers a period of two years. The hours are long and the pay is small. The "experience" gained by the student may or may not justify the sacrifice. "It depends largely on the man." In the meantime the large company has a good opportunity to select the material which it requires for its own use, and perhaps 25% of the shop graduates have reason to feel enthusiastic over the system; the others pass through days and nights of discouragement, and many leave the shop with a sense of failure, which is sure to have an influence on their future.

LEVI MECHANICAL FILTERS AT CHARLESTON-KANAWHA, W. VA.

A mechanical filter plant with a water collecting system and sand screens of unusual design has been in use at Charleston-Kanawha, W. Va., for about four years, and a similar plant at Mt. Sterling, Ky., since June, 1902. Both plants are of the pressure type and neither makes use of either stirring devices or compressed air in washing the sand. Revolving bars, however, are used to prevent clogging of the screening system by sand.

Water-works were built at Charleston in 1885-6, by the Charleston Water-Works Company. The works are now controlled by the Kanawha Water & Light Co., and the name of the town has been changed to Charleston-Kanawha.

The water supply, as far back as "The Manual of American Water-Works" for 1888, was described as follows:

> Elk River, by direct pumping, water being admitted through inlet pipe to suction basin, and pumped through filter to city when water is muddy.

The filter then in use was one of the earliest of the mechanical filters ever built (the Hyatt), and had a rated capacity of 500,000 gallons. Up to the close of 1896, at least, the water supply remained about as already described. In 1897, a settling reservoir, with an available storage capacity of about 800,000 gallons, was built, and in or about 1900 the old Hyatt filters, which had then been in service 13 years, were replaced by six units of Levi filters, to which two units were added in 1902. Each unit has a daily capacity of 150,000 to 250,000 gallons, which for a filtering area 7 ft. in diameter, or 38.5 sq. ft. in area, gives a rate of 200,000,000 gallons per acre per day. (Acre = 43,560 sq. ft.)

Water, when turbid, is pumped from Elk River to the settling reservoir, which is 100 × 100 ft. in plan at the water line, has slopes of 1 ft. horizontal to 5 ft. vertical, and a water depth of about 12 ft. The high water line in this reservoir is 220 ft. above the level of the sand in the filter beds.

From the filters the water passes through a 10-in. main directly to the consumers, under a domestic pressure of 60 lbs. and a fire pressure of 90 to 110 lbs. When the water in the river is passably clear, the water is pumped through the filters and to the consumers, direct, without going to the settling basin. When it is turbid the settling basin is used, and coagulant at the rate of ½ to 1½ grains per gallon is employed. Of this, two-thirds is applied in the water (the pump discharge), which goes to the settling basin, and one-third at the filters. The average quantity of water filtered is given as 2,000,000 gallons in 24 hours.

Fig. 1 shows one of the filter units in sectional plan and elevation, and Fig. 2 shows the details of the water-collecting system, including the screens, screen cages and the rustling bars. Each filter is provided with twelve radial collectors, which discharge into a central manifold. The screens are double, and together form a frustum of a cone. They are of sheet copper, perforated, and their edges are bent outwards on the lines of their horizontal diameters. They are protected above and supported below by cast-iron cages, as shown in detail by Fig. 2. Within each double screen, and fitting closely against it, is a revolving bar, called a rustling bar, with a shank extending through a stuffing box in the cap just mentioned. The rustling bars are revolved by hand, by means of a wrench, while the filter sand is being washed. By revolving the bars any sand in screen perforations will be dislodged. By drawing off the water from any filter unit and removing the proper cap, any rustling bar or screen can be removed without disturbing the filter bed.

From 8 to 12 minutes is required to wash each

filter, and a meter measurement has shown that the wash water is supplied at the rate of 13 cu. ft., or about 100 gallons per minute. The filter unit tested had a capacity of 150,000 to 250,000 gallons per 24 hours. At an average of ten minutes per washing, and only 200,000 gallons per

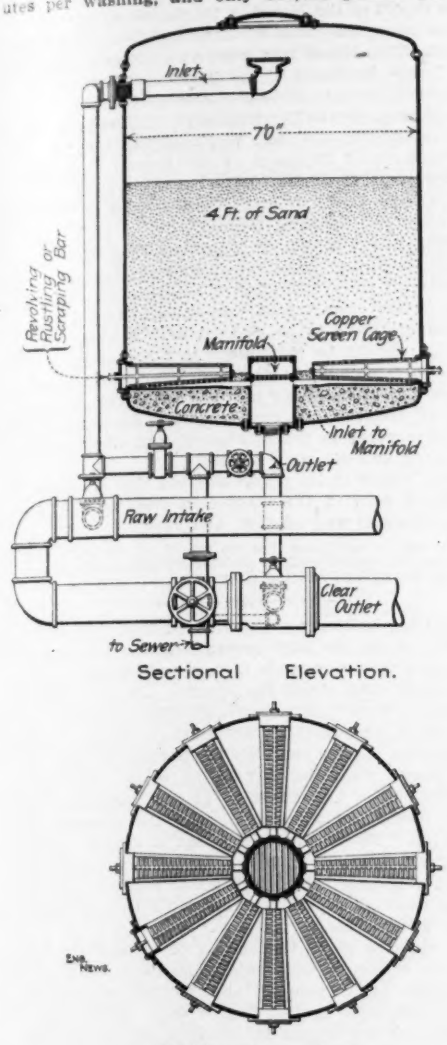


Fig. 1. Sectional Plan and Elevation of Levi Mechanical Pressure Filter.

unit per day, the wash water would amount to only 0.5% of the quantity filtered for each washing. From 2 to 4 washings are required per 24 hrs. This makes no allowance for water wasted immediately after washing, which, however, is very small.

The type of filter described was designed and some of its features have been patented by Mr. M. Levi, and the filters are manufactured by the Levi Filter Co., of Charleston-Kanawha, W. Va. We are indebted to the company named, and also to Mr. J. H. Levi, Assistant Superintendent of the Seabury shipyard, Morris Heights, New York city, for the information used in preparing this article.

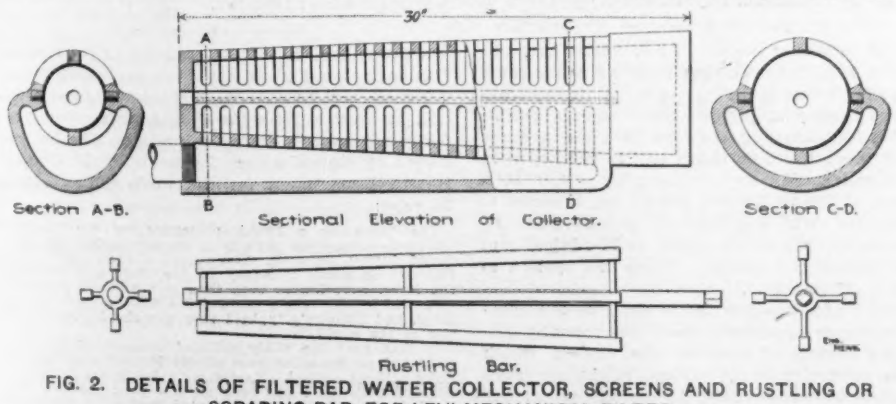


FIG. 2. DETAILS OF FILTERED WATER COLLECTOR, SCREENS AND RUSTLING OR SCRAPING BAR, FOR LEVI MECHANICAL FILTER.

MUNICIPAL OWNERSHIP and operation of street railways was approved by a large majority of the voters of Chicago in a referendum vote on April 5. Of the several propositions voted on, one was the approval of the Mueller law, passed by the last Illinois legislature authorizing cities in Illinois to construct, own, operate and lease street railways. On this the vote was 152,433 in favor, and 30,104 against. On the question whether Chicago should take over the street railway properties, the vote was 120,744 in favor, and 50,893 against. A still larger majority was given to permit the temporary licensing of street railways until the city is prepared to take possession of them.

A NEW WATER SUPPLY for Springfield, Mass., to be taken from the Westfield River near Huntington has been recommended by Messrs. Samuel M. Gray and Geo. W. Fuller, Consulting Engineers to the city. The total cost for a supply of 25,000,000 gallons daily is set at $3,786,490, exclusive of filtration which is estimated to cost about half a million dollars additional. The present water consumption of Springfield is about 9,435,000 gallons daily or about 150 gallons per capita, a very high figure for a New England city. The reason for the high consumption is partly the use of water for motive power. It was found that ventilating fans in the public schools were using 825,000 gallons of water per day. It is also believed that large leaks exist in some of the old cement lined iron pipe which is still in use. If measures are taken to stop leakage and restrict waste, it is believed that a supply of 15,000,000 gallons will suffice for the city for 30 years to come, and the cost of the plant would be reduced to $2,210,875.

THE SEWERAGE SYSTEM of Boston and vicinity is being changed from the combined to the separate system, and property owners are being compelled to alter their plumbing and drains from roof leaders so that no storm water shall be discharged into the sewers. In order to compel this change, an act was passed at the last session of the legislature, one section of which reads as follows:

> The owner of every estate abutting on a public way, in which a drain and a sewer shall have been provided by a city or town, and the owner of every other estate using such drain or sewer, shall make or change the plumbing of his estate so that the waters shall be kept separate from the sewage, and shall make connections for, and conduct, the water into the drain and the sewage into the sewer; and the owner of every estate whose sewage is to be taken into the metropolitan sewer shall hereafter in plumbing his estate so arrange the plumbing as to keep the water separate from the sewage.

It is expected that the complete work of separating sewage from storm water in the city of Boston will require some eight or ten years.

AN INTERCEPTING SEWER AND SEWAGE PURIfication plant have been recommended for Utica, N. Y., by Mr. Geo. W. Rafter. On account of the lack of sand and gravel deposits, septic tanks and contact beds are recommended for the purification.

THE MOST SERIOUS RAILWAY ACCIDENT of the week was a butting collision on the Pennsylvania R. R. at Pottsville, Pa., on April 2. Due to an error on the part of a freight train in following orders, it collided with a passenger train. Two men, one of them a passenger, were killed outright.

RAILWAY ACCIDENTS IN CHICAGO during March resulted in 38 deaths; 5 of these occurred on the surface electric railway, 1 on the cable lines, 1 on the elevated railway, and 31 on the steam railways. There were 81 accidents on the surface electric lines, in which 86 persons were injured and five killed.

A VERDICT AGAINST A WATER COMPANY for fire damage, amounting to $35,649, was rendered at Shreveport, La., March 19, in the case of the Allen & Curry Mfg. Co. vs. the Shreveport Water-Works Co. The claim for damages was based on the fact that when the plaintiff's mills caught fire, the fire companies were unable to operate a hydrant on which the works relied for fire protection.

THE ARCHITECTURAL DECORATION of the Manhattan Bridge over the East River, designed by Mr. Henry F. Hornbostel, has been rejected by Commissioner of Bridges Best and the work of designing new architectural decorations has been entrusted to the firm of Carrere & Hastings.

STANDARD THREADS FOR COACH AND LAG screws have been adopted by a considerable proportion of the manufacturers of these goods, according to information furnished us by the New Jersey Foundry & Machine Co., makers of an expansion shield made to fit this standard threading. The standard referred to is as follows:

Diam. of bolt, ins.	No. of Threads per in.
5/16	9
3/8	7
1/2	6
5/8	5
3/4	4½

THE LARGEST AMERICAN BATTLESHIP, the "Virginia," was successfully launched on April 5, 1904, at the yard of the Newport News Shipbuilding Co., Newport News, Va. The vessel is 435 ft. long and 76 ft. 2½ ins. broad on the water line, with a maximum full-load draft of 26 ft. The trial displacement, with draft about 23 ft. 9 ins., will be close to 15,000 tons. The speed will be at least 19 knots. The engine equipment comprises two triple-expansion engines of four cylinders each, aggregating 19,000 I. HP., driving twin screws. The boilers, 24 in all, are of the Niclausse water-tube type; they are arranged in six groups of four each, in separate watertight compartments. The normal steam pressure is 250 lbs. per sq. in. In addition to the main engines and their auxiliaries, some 1,000 HP. of steam-driven electric generators are provided, in units of 80 and 160 KW. The pressure is 125 volts, the new Navy standard. Current from these generators is utilized, besides for lighting, for almost all auxiliary power purposes outside of the engine-room. The turret-turning gear, the ammunition hoists, etc., are all motor-driven. Accommodations for 812 men, including officers and crew, are provided.

The main battery of the "Virginia" consists of four 12-in. guns (40 calibers long), mounted two each in a forward and a rear turret; eight 8-in. guns, of which four are mounted in turrets superimposed on the 12-in. turrets, while the other four are in two broadside turrets; and twelve 6-in. rapid-fire guns, six on each side. Beside the secondary battery, the vessel is also fitted with submerged torpedo tubes. The main armoring comprises a waterline belt 8 ft. wide, 11 ins. maximum thickness, tapered to 4 ins. minimum; a casemate armoring of 6 ins. entirely enclosing the 6-in. guns; 12-in. and 8-in. turret armor, and a protective deck varying from 3 ins. on the slopes to 1½ ins. on the flat. A 3-ft. belt cofferdam, packed to a density of 8 lbs. per cu. ft., extends along the sides above this deck.

The "Virginia" is the first of five similar vessels, three of which were authorized in 1899 and two in 1900. The intention was to make them the best war vessels afloat, in efficiency, fighting power and speed, combined.

A NEW PLAN FOR A LIGHTHOUSE ON DIAMOND SHOAL has been presented to the House Committee on Interstate and Foreign Commerce, at Washington, by Capt. Albert L. Eells, a seafaring man. He proposes to build at Newport News a bell-shaped metal caisson, 70 ft. in diameter at the bottom and 27 ft. at the top, and apparently about 60 ft. high. He would then load this caisson until it drew 29 ft. and tow it to the site of the light on the Shoal at a point where there is 30 ft. of water. By opening valves provided, he proposes to sink the caisson, and by at once starting powerful pumps to further settle the structure in the sand. The caisson is then to be filled with concrete and a circular steel base would be built upon this foundation, with a diameter of 25 ft.; upon this would be erected a circular steel lighthouse with the light not less than 200 ft. above mean low tide. The bill as framed provides that no payment is to be made by the Government until the light has been built and maintained by the contractor for 12 months and then maintained for four years more by the Lighthouse Board. After it has been approved by the Government Engineers and has stood five years, the Government is to pay for it $500,000, the $90,000 representing interest at 4%.

AN INDUSTRIAL EXHIBITION will be held at Cape Town, South Africa, during the three months, November, 1904, to January, 1905. The site of the exhibition is Green Point Common, to which a "light railway" from the docks will carry the shipments of exhibitors. The exhibition grounds will be a bonded store, by permission of the Cape Customs, so that unsold exhibits can be shipped back free of duty charge. Special conveniences will be granted to exhibitors desiring to show machines in operation, or to conduct actual manufacturing processes. The American agents for the exhibition are Pitt & Scott, Ltd., of 30 Broadway, New York City.

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Old readers of Engineering News will doubtless recall the hot controversy which was waged in the engineering profession some 15 years ago between the advocates of straight and curved dams. Some conservative members of the profession insisted that a dam ought to be built like a retaining wall, and that if it were built on a curve the combination of arch action and retaining wall action would be apt to set up unknown and dangerous stresses within the masonry. On the opposite side were ranged engineers who defended the curved dam and the gravity dam with curved face as being more economical of material and less likely to suffer from cracking by temperature stresses. Prominent among these latter engineers was the late A. M. Wellington, at that time one of the editors of this journal.

It is of interest to recall this discussion of former years in connection with the remarkable series of dams which are illustrated in the present issue of Engineering News, particularly the remarkable structure in South Australia, which for boldness of design deserves to rank with the most famous dams of the world.

It is probably correct to say that the arched dam is much more favorably regarded in the engineering profession to-day than it was a dozen years ago. This is due not alone to the success which has been attained in the construction of arched dams of bold design, but to the increasing use of concrete instead of masonry in dam construction. In dams built of ashlar masonry, the engineer had much reason for preferring a gravity dam, in which the stresses would be simply those of compression acting at right angles to the beds of the several courses. In a monolithic concrete construction, however, the material can resist compression equally well in any direction, and a concrete wall acting both as an arch and as a gravity dam is probably better able to resist the combined stresses than it would be if it were acted upon by either one alone. By combining steel tensile members with the concrete to tie the structure together and resist temperature stresses tending to cause cracks, a masonry structure is obtained, better able to resist diverse stresses and temperature effects, it may well be believed, than the best of the cut stone masonry of earlier days.

It is worth noting here, however, that the strength of a concrete structure depends entirely on the quality of the concrete, and an engineer in charge of an important structure is justified in taking extraordinarily pains to secure uniformity and reliability in the concrete. The methods used at the Barossa dam to this end were quite different from anything in American practice and are well worthy of study.

Finally, one of the stock objections raised by the opponents of concrete is the effect of temperature stresses in producing cracks. We would call particular attention to the fact that this great concrete dam, nearly 100 ft. in height and almost 500 ft. in length, is located in a climate where the temperature ranges from 30° to 168° F. The fact that this thin wall of concrete withstands these extremes without cracking furnishes remarkable testimony in favor of curved dams as compared with straight, and in favor of steel reinforcement for concrete exposed to temperature stresses.

Remarkably prompt action has been taken by New York City's financial authorities for the construction of the high-pressure fire protection mains recommended by Messrs. Hill and De Varona in the reports published in our issue of March 24. The Board of Estimate and Apportionment at its meeting on March 31 voted an appropriation of $5,425,400 for this purpose, of which nearly $4,000,000 is allotted to Manhattan, and the remainder to Brooklyn.

While the newspapers continue to talk of the scheme as the "salt-water plan," there is every reason to believe that when installed the system will actually use fresh water, and salt water will only enter the mains in case the fresh-water supply proves inadequate or it becomes necessary to use fireboats in addition to the regular pumping stations. Messrs. Hill and De Varona in their reports each urged that fresh water be used in the system, with merely an emergency suction connection from the pumping station to the rivers, and they might have made a much stronger argument against the use of salt water had it seemed necessary. It is not merely a question of shorter life for mains, hydrants, etc., if salt instead of fresh water is used in them. Engineers experienced in handling brine or sea water in pipe systems can testify to the difficulties with valves and gates, which stick when left long shut and leak when opened and closed again. Packing of stuffing boxes hardens and loses its life, and rust and scale from the interior of the pipes lodges in the valve seats. Salt water alone is bad enough in its effect on metals, but the salt water in the East and North Rivers is contaminated with a large volume of sewage and with acids from all sorts of chemical works and it carries frequently a large amount of sediment in suspension. If it were necessary to introduce this water into a system of high-pressure piping for fire protection purposes, it might doubtless be done; but since fresh water can be used equally well, to take the large risks attendant on the use of salt water would seem of very doubtful expediency.

The advocates of the use of salt water, however, bring forward the argument that the water could be used for washing the streets and thus the high-pressure system of piping would serve a double purpose. Concerning the idea that the average street cleaner could be safely left to monkey with the hydrants of a system carrying water at a pressure of 250 to 300 lbs. per sq. in., it seems to us that Mr. Hill was entirely correct when he characterized this in his report as ill-advised and impracticable, and liable to cause the system to fail at a critical time.

We may add, however, what some of the amateur engineers apparently have not thought of—that the system of washing the streets, which looks so attractive on the surface, might not prove so successful when tested by actual experience on a large scale. In a city with sewers laid on grades steep enough to clear themselves of sand and sediment, it may be all right to flush everything into the sewers. It may work successfully in Paris, too, where the sewers are of a size unknown anywhere else in the world, and are especially planned and equipped for the removal of deposits. In New York City, however, it is, we believe, a good deal cheaper to shovel street dirt from the pavement into a cart than to laboriously hoist that dirt out of a sewer catchbasin.

It is interesting in this connection to refer to the report of the Board of Engineers appointed to pass upon the plans of Messrs. Hill and De Varona. This Board was made up of Messrs. Nelson P. Lewis, Engineer of the Board of Estimate and Apportionment; Horace Loomis, Chief of the Manhattan Sewer Department; J. C. Brackenridge, Commissioner of Public Works of Brooklyn; J. A. Briggs, Chief Engineer of the Bronx; J. J. McLaughlin, Consulting Engineer of Queens Borough; and L. L. Tribus, Commissioner of Public Works for Richmond Borough.

This Board stated in its report that while the Street Cleaning Department strongly favored the system of street cleaning by flushing with water, the Sewer Department was equally urgent that, if streets were to be cleaned with a hose, catch basins should be introduced into the sewer system to intercept the dirt and litter which would otherwise find its way into the sewer system, and it was declared that such a system would mean a large increase in the number of men employed in flushing and cleaning sewers.

The Board in its report advised that the street flushing part of the scheme be tried only in an experimental way at first, and added

> We are not convinced that the use of salt water for this purpose will prove entirely satisfactory and sanitary, owing to the pollution of the river water.

It must be freely acknowledged that the use of water from the high-pressure mains for street cleaning purposes tends to very considerable complication throughout the system. As the use of water at very high pressure directly on the street is out of the question, two alternatives have been proposed. Under one plan the normal pressure in the mains would be only 50 lbs. or so, and at an alarm of fire the engineer at the pumping station would immediately run up the pressure to 300 lbs. Under the other plan a special street cleaning hydrant with a reducing valve attachment is proposed, by which water would be drawn from the high-pressure mains and delivered to the hose at a moderate pressure.

It appears to us that either of these plans involves elements that might interfere with the efficiency of the primary object of the whole system—protection against fire. Without taking space to discuss the matter in detail, it will be evident to engineers that to suddenly raise the pressure on a large system of mains from 50 lbs. to 300 lbs. at the outbreak of a fire, might cause a break and cripple the system at just the time it was most needed. As for the reducing valve hydrants, it may be suggested that the expenses of keeping in repair these hypothetical pieces of apparatus might very properly be charged to the Street Cleaning Department, and might largely offset the expect economy to be made, through the use of water for street cleaning.

An excellent test of the capacity of the Chicago Drainage Canal to do the work for which it was designed, viz., protect the Lake water from pollution by outflow from the Chicago River, has been furnished by this spring's freshets. The bulletin issued by Commissioner Reynolds of the Chicago Health Department for the week ending March 26 says:

> The value, as a health protection, of the Drainage Channel—incomplete though it is—was strikingly manifested during the week. The waters of the streams about Chicago, formerly tributary to the river and thence to the Lake, were higher even than in the record year 1892—in which year there were 1,489 deaths from typhoid fever, and Chicago's typhoid rate was the highest of any city in the world.
>
> In that year the vilely polluted contents of the main river and its branches were poured incontinently into the Lake without control. Except for a few hours during the 23d and 24th there has been no flow from the river into the Lake during this unprecedented freshet. A volume of from 600,000 to 700,000 cu. ft. per minute has been poured steadily through the Drainage Channel away from the Lake down the Des Plaines Valley. If 1904 escapes the typhoid tragedy of 1892 it will be due solely to the agency of the incomplete Main Drainage Channel.

In fixing the capacity of the Drainage channel, the engineers had to provide a sufficient flow to dilute the sewage of the city with lake water

and prevent a nuisance to the residents of the Illinois Valley. They also had to provide capacity sufficient to carry off the flood discharge from the Chicago River watershed and prevent the reversal of its current toward the lake. From the above statement it would appear that the recent flood has given the channel a more conclusive test in this particular than it has experienced since its completion.

IS THE AM. SOC. C. E. STANDARD RAIL SECTION THE BEST FOR THE OUTSIDE RAIL OF SHARP CURVES?

Many of our older readers will remember the "battle of the rail sections" which took place some 20 years ago, when there were as many ideas, nearly, concerning the proper design of rail sections as there were railway chief engineers. Order was brought out of this chaos by the work of the American Society of Civil Engineers' Committee on standard rail sections, and the "Am. Soc. C. E. section" was universally accepted by American engineers as a long step in advance.

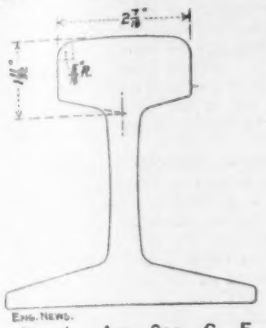


Fig. 1. Am. Soc. C. E. Standard Rail Section.

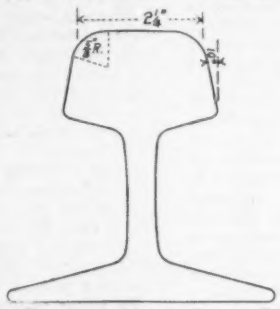


Fig. 2. Lehigh Valley R. R. Standard Rail Section, 1883.

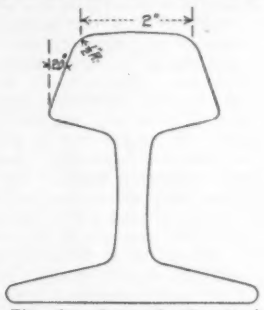


Fig. 3. George's Creek & Cumberland R. R. Standard Rail Section, 1883.

Fig. 4. Section of Rails Originally Used on Darjeeling-Himalayan Ry., India.

(Shaded Portion is Part Worn Away on Sharp Curves.)

Fig. 5. New Section of Rail for Darjeeling-Himalayan Ry.

The most notable feature of the Am. Soc. C. E. rail is the vertical sides of the head and its sharp top corners. A few years previous to the adoption of this standard, a type of rail section originated on the Lehigh Valley Ry. and came into extensive use, in which the sides of the head were sloped outward. For a time this form of rail head was strongly advocated. It was argued that it wore better and was less destructive on wheel flanges than any rail which had preceded it. The Am. Soc. C. E. section with vertical sides and sharp top corner was condemned when first brought forward on the ground that it would cause sharp wheel flanges. The evidence in its favor, however, was so conclusive that the advocates of the Lehigh Valley section yielded and practically confessed that they had been mistaken.

This ancient history is brought freshly to mind by a report just received from India from which we learn that a rail section very similar to the old Lehigh Valley section, with its flaring sides, has been adopted on the Darjeeling-Himalayan Ry. and also on the Kalka-Simla Ry., and is heralded as a distinct advance over preceding practice.

The first-named railway is a 2-ft. gage line having a large proportion of its length made up of curves of 70-ft. radius with some curves as sharp as 60°. The rails originally laid on this road had a broad head with sides sloping inward, and the Chief Engineer describes his experience with them as follows:

> The wear was found to be very rapid within the first six months, and was confined entirely to the inner shoulder of the rail-head of outside rail on curves. The subsequent wear was slower and more uniform, occurring along the whole of the inner face of the rail on curves, so that the comparative wear of rails between five and fifteen years' life in the road is not very marked.
>
> When renewals of rails had first to be considered after fifteen years' wear on a few of the very sharp curves, the company, after some deliberation decided to adopt a rail section based on the sectional profile of their worn rails.
>
> The wear of the new rail after thirteen months' service on a curve of 70 ft. radius is such that the adoption of the design is considered to have been fully justified. All renewals on the hill section now required are to be with the new section rail.

Confirming this observation the Chief Engineer of the Kalka-Simla Ry. said:

> My own observations while in charge of 5 ft. 6 in. gage railways in the Punjab had already brought it home to my mind that on sharp curves and severe grades rail heads never retained their original shape for more than a few weeks, or months; they invariably and rapidly wore down; after which the rate of abrasion slackened off, and the abraded cheeks lost their brightness and frequently tended to become rusted. In this state the rails were left for years in the line and did their work well.
>
> On seeing the Darjeeling new type, I at once came to the conclusion that it was of the best possible shape, presenting as it did to the wheels a surface which my previous experience taught was such as was automatically assumed by rails under conditions of severe wear. I realized that by adopting this section at first, undue abrasion both of rails and of wheels would be minimized; and I decided then and there to adopt the same new type for the Kalka-Simla Railway.

It will not escape notice that these Indian engineers approve this section specifically and only for use on sharp curves. This point is of particular interest because when the question of standard rail sections was under discussion in the 80's, those who favored the Lehigh Valley section with its flaring sides were the engineers in charge of roads with a large amount of curvature, such as the Lehigh Valley itself, while the road after whose standard section the Am. Soc. C. E. section was patterned was the Michigan Central, a road in a level country with few and easy curves.

Further than this, we believe that the question as to the best rail section for curves was left open when the Am. Soc. C. E. standard was adopted. The committee said (Trans. Am. Soc. C. E., Vol. XIX; p. 36):

> It is a well known fact that it is only the outside rails of curves which wear to a larger radius [than the original top corner] to fit the fillet of the wheel-flange. Whatever the original form, all inside rails on curves and all rails on tangents wear in time to a very sharp corner. As an average of the whole United States, curves constitute about 25% of the whole mileage, and hence outside rails about one-eighth.

In other words, the Am. Soc. C. E. section was specifically designed for wear on tangents and the question whether some other section might wear better for the outside rail on curves has never, so far as we know, been definitely settled.

While it is true that the outside rail on curves is a small percentage of the total railway mileage, it is also true that on roads of the heaviest traffic the wear on these rails is so heavy that they account for a large percentage of rail replacements. Thus, if it were true that some other rail section than the standard would wear better on the outside of curves, it would be worth while to use such rails on some of the sharp curves of roads hauling heavy traffic. As our readers will remember, a special rail section for curves designed by Mr. W. T. Manning,* when Chief Engineer of the Baltimore & Ohio, was laid on the Baltimore & Ohio and Pittsburg & Western railways a few years ago, and the Pennsylvania Railroad has gone to the expense of purchasing nickel-steel rails for sharp curves on its main line.

It is within the bounds of possibility, therefore, that the rail section adopted by these engineers in India for crooked mountain railways may have a practical interest for American engineers.

LOWERING THE COST OF MACADAMIZED ROAD CONSTRUCTION IN MASSACHUSETTS.

Upon studying the annual reports of the Massachusetts Highway Commission, covering a period of ten years, an engineer is impressed with the fact that while the early road work was done at a cost of about $10,000 a mile for a 15-ft. macadam road, including engineering expenses, the work is now being done for $6,250, exclusive of bridges and exclusive of salaries and office expenses of the Commission and its principal assistants. These salaries and office expenses amount to about $500 a mile, and it is probable that bridges and culverts add another $600, making the present cost about $7,350 a mile for a 15-ft. road.

This striking reduction in cost has occurred in the face of advancing cost of labor and materials. The last annual report is unfortunately not sufficiently complete to show exactly where and how the reduction in cost has been effected; but we may, with safety, say that it is largely due to the recent adoption of a policy by the Commission which in their own words is as follows:

> In the opinion of the Commission, it is more economical to take the chances on certain doubtful soils, remedying the defects which may develop later, and by so doing save useless work.

This is sound engineering, and it is the kind of engineering that should oftener characterize the management of public works of this character.

In the early days of road building in Massachusetts, however, the Commission acted wisely in "*not* taking any chances." They designed and built roads in a substantial, and in a correspondingly expensive, manner. In that experimental stage of the work, had inferior rock or thin metaling led to a rapid failure of even one or two prominent roads, there would have been an outburst of public criticism that might have given road building by State aid a serious setback. With the growth of favorable public opinion and with the increase in appropriations the Commission has found itself able finally to adopt a policy that as engineers for a private corporation they would probably have adopted at the inception of the work. It has been urged that they were too slow in adopting this policy of building cheaper roads and afterward remedying defects as they appeared. In a State of less wealth than Massachusetts this criticism would have greater force. The engineer in charge of public works has to balance, as his judgment tells him is best, the risk incurred by building cheaply against the risk incurred by spending public money in a seemingly lavish manner. He cannot argue with the public as he would with the directors of a company. He knows that even a partial failure of his work is likely to be seized upon as an evidence of incompetency, although it may in reality be the evidence of the highest degree of competency. A low factor of safety in road building endangers neither life nor property, yet it is impossible to convince the public that the untried engineer, who, in a few instances, provides too low a factor of safety, may nevertheless be a capable man, acting in the best interests of the public. The tendency of engineers in public office is, therefore, always to build in a manner that might be called extravagant in order to be sure of the strength, durability and fine appearance of their work. We recall no instance of loss of position or prestige due to building public works in this manner.

In view of these facts an engineer in public office should guard against a long continuation of what may be termed extravagant construction; and having once established his reputation in the public eye, he should seek gradually to reduce the cost of construction by the use of materials less expensive, and by the use of lower factors of safety—wherever life or property are not im-

*See Eng. News, Feb. 9, 1899, p. 94.

perilled by such changes in design. Roads and pavements are pre-eminently fitted for safe experimenting of this kind.

In New York State, the State Engineer is working toward an eventual reduction in the cost of roadway in many ways. Roads built entirely of shale, so soft that it needs no crushing, but is crushed under the steam roller, have proved a decided success where the traffic is light. Telford construction has been rarely used in New York from the very beginning of State roadwork, and in Massachusetts it has been abandoned because a gravel foundation is equally effective and cheaper.

To put into a nutshell the present tendency in both these States, we may say that the policy is, first to pave the road with local materials, such as gravel, shale and crushed field stone; if the thickness is not great enough to hold up the loads, then it is subsequently increased; if the material is not tough enough to stand the wear that comes upon it, then a wearing coat of imported material is placed upon the road.

In closing, we may, with possible advantage, indicate one other line along which it is possible to work in securing a greater mileage of roads at moderate cost. We refer to the narrowing of the paved width.

From 12 to 16 ft. is now the common width of macadam roads. Why are the roads which carry comparatively light traffic not built 6 to 8 ft. wide with turnouts say every 500 to 800 ft. apart? The plank roads of the State of Washington are built 8 ft. wide with turnouts 16 ft. wide at short intervals.

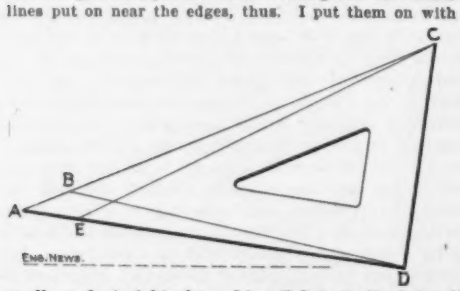
It is noticeable, also, that where towns own their own rock crushers very commonly the macadam is laid on the old earth road and is given a width but slightly greater than the gage of the wheel ruts in the earth. We are now building roads that are double-track trunk lines radiating from the larger centers of population in New York, Massachusetts and New Jersey; but the time is rapidly approaching, if indeed it is not already here, when single-track macadam roads will be built as feeders to these double-track roads.

LETTERS TO THE EDITOR.

A Method of Drawing Side-Slope Lines.

Sir: A contrivance which I have found very useful and have never seen elsewhere may be of interest to your readers.

In putting slope lines on cross sections of embankment or cutting, a transparent celluloid triangle 30°-60° has two lines put on near the edges, thus. I put them on with a



needle and straight-edge. Line E C is inclined to side of triangle A D, as 1½ to 1, which is the usual slope in this section of the country. B D is inclined to A C in the same ratio.

In using this triangle the pencil is placed at top of embankment slope, the triangle turned till the line E C is coincident with one of the horizontal ruled lines on the paper and the side slope line drawn along the edge E D. This avoids counting lines or using parallel motion on the ruled paper which is, at best, trying on the eyes.

Yours truly, H. K. Higgins,
Asst. Engr., N. Y., N. H. & H. R. R.
472 South Station, Boston, Mass., March 24, 1904.

Influence of Composition of Concrete on Horizontal Shear in Concrete-Steel Beams.

Sir: Relative to the recent discussion in your columns concerning the liability of reinforced concrete beams to fail by reason of the effects of horizontal shear, I beg to say that it seems to me that the crucial point has been omitted from the discussion. The fact is that the liability to failure through horizonal shear, and the necessity for the presence of a mechanical bond other than natural adhesion between the steel and the concrete, is, in the writer's opinion, wholly a matter of richness or leanness of the concrete. He has not been able to bring about failure by horizontal shear even when the ratio of length of span to depth of beam is as low as 5, in beams composed of 1:2:4 concrete. A failure accompanied by a pulling out of the bar, such as Mr. Schaub has described, has occurred in concrete as lean as 1:3:6. It is to be noted that Professor Lanza's tests on 8-in. × 12-in. beams in which failure occurred mostly by horizontal shear were based on 1:3:6 concrete.

Very truly yours, W. K. Hatt.
Lafayette, Ind., March 12, 1904.

Concerning the Degree of C. E.

Sir: In the Engineering News of March 3, you give an answer to a question regarding the use of the letters C. E. after one's name that I hope will give rise to further discussion. I have always understood that the letters C. E. after one's name could legitimately mean only one thing; namely, that the person thus writing his name had received the degree of C. E. from some engineering school. The editor evidently does not take this view; and he certainly would not say with reference to a man upon whom the academic degree of M. A. had never been conferred, "If such a man derives any satisfaction from writing M. A. after his name, we see no impropriety in his doing so."

It seems to me that the professional degrees more than any other should be protected. No one will dispute the fact that many C. E. degrees (just as many M. D. and M. A. degrees) are given unworthily. And it is equally true that many a practicing engineer, not having the C. E. degree, knows more engineering and is far better equipped for usefulness than his brother who has perchance a C. E. degree from one of the best engineering schools in the country. When the editor of such a journal as the Engineering News advocates a loose use of the letters "C. E." after an engineer's name, he strikes a blow at the C. E. degree. If, as the editor implies, there has always been confusion as to what C. E. after a name means, then it seems to me that all engineers, and especially editors and teachers, should use their influence in bringing about a proper recognition of the degree of C. E. As I have not a C. E. degree, I write in a purely impersonal way. Saml. M. Barton.

University of the South, Sewanee, Tenn.,
March 25, 1904.

The Shrinkage of Earth Embankments.

Sir: The article in regard to the shrinkage of earth embankments, and the comments thereon, which have appeared in Engineering News of late, have been of interest to the writer, showing as they do the extent to which the writing of specifications is governed by precedent.

To state in a specification that the earth in an embankment will measure either more or less than the excavation from which it is to be made, and the amount of the difference in measurement seems to the writer unwise, likely to cause injustice, and cost some one money needlessly.

As a matter of fact (from the writer's experience) it may measure either more or less than the excavation. In fact at a certain period of time it will do each, and the question which condition will be apparent at the time of measurement is determined not so much by the manner of placing, as by the weather conditions during the time, and the relative length of time consumed in placing the material in the embankment.

The writer has known earth fills, made by wheel scrapers in the manner usual on railroad work, in layers of about five feet depth, to measure considerably more than the excavation, simply because they were made quickly and in a dry season.

Deep fills of earth made by dumping from carts at grade where the amount of compacting due to the wheels and animals was small, the writer has also known to measure less than the excavation, but only when the progress was slow and the weather wet.

That earth fills do eventually settle is shown by the long sags in the track on some railway embankments, but it is not generally apparent at the time necessary to lay the track, or when the final cross sections are taken. The writer remembers a "general order" which required all earth fills to be increased 10% in height, and also remembers putting the wheelers on and taking off nearly the entire amount of increase before the track could be laid to grade.

In general, the shrinkage of earth is a very uncertain quantity and it would seem better to measure all earthwork in excavation even if the "potholes" and stumps are difficult to measure, for if any guessing is necessary one can at least see what he is guessing at.

E. G. Haines, Assoc. M. Am. Soc. C. E.,
Resident Engineer, Division No. 1,
Atlantic Ave. Improvement.
5 Hanson Place, Brooklyn, N. Y., March 22, 1904.

Criticism of Overhaul and Clearing Clauses in Specifications.

Sir: With reference to the discussion between Mr. Fonda and Mr. Beard in regard to the overhaul clauses quoted by Mr. Fonda in the Engineering Literature Supplement of your issue of March 17, page 26:

The writer advances the opinion that in case a contractor on this work had contested the ruling of the engineers in regard to the manner in which the work was paid for, that the courts would have held that the two clauses in the specification are in conflict with each other, and that therefore the question should be decided according to the equities in the case and the governing custom. In which case the contractor would almost certainly have won his suit.

It would be a hard matter to convince judge or jury that under the first and most important clause defining the manner of making payment for overhaul which reads: "The price per cubic yard shall include all material hauled a distance of not exceeding five hundred feet, etc.," that a contractor could with any justice be compelled to haul any material whatever as much as 1,000 ft. without extra pay therefor.

Further, the full meaning of the second clause is obscure. The writer read it in the book without ever appreciating its full meaning until the effect of it was brought out by Mr. Fonda. That Mr. Fonda also thought its meaning might be obscure to other engineers, who might not see into it quite so clearly as he, is evident because he thought it necessary to illustrate its meaning with a concrete example. Thus, is it not extremely probable that in this case some contractors were, without any such intention on the part of the engineers, misled? A contractor might even be tempted to use a stronger word than misled.

In this particular case all possibility of misleading the bidder could have been avoided by inserting another sentence in the last clause as follows: "The effect of this will be that the free haul on earthwork will oftentimes be considerably greater than 500 ft." One can hardly doubt, however, that the effect of such a clause would have been to raise the bid on the excavation price.

The writer believes that much of the obscurity with which engineering specifications are oftentimes surrounded has descended from the legal profession to whom it was formerly the custom to entrust, for the most part, the wording of all contracts and specifications. The circumlocution and subterfuges which oftentimes have a place in legal writings are wholly out of place in engineering specifications. For these should be couched in this country in such simple and plain English that "he who runs may read, and, reading, may understand."

Assuming that an engineer has good cause for letting a contract in some particular manner which is not the wholly uniform custom, or assuming that it be found impossible to so word a specification as to prevent all possible misunderstandings, why is it not good engineering practice to illustrate the intent of the specification by a concrete example, notwithstanding the fact that our legal advisers will usually rule out the concrete example on the grounds of a lack of dignity, or, of making the provisions too specific.

For instance, in the practice of the writer he has been very much troubled by the specifications under which he has had to work which governed the manner of payment for clearing of right of way. The early specifications under which the writer worked said: "No payment shall be made for clearing except where clearing occurs." In another case the clearing was to be paid for by measuring the "area covered by the overhang of the branches." The writer could cite some still more ridiculous cases which he has seen, but it will suffice to say that under the second way of wording the specifications the writer found that he had to allow the contractor the same amount for clearing away a sumac thicket which cost about $2.50 an acre as for a dense woodland which cost $35 an acre.

To cover the difficulty the writer devised the following wording for the clearing specification which he has never seen used in any but his own contracts. The writer does not offer it as removing all difficulty in a vexing minor subject in railroad construction in a country where the timber covering is variable. But so far as the writer knew the wording of the specification was unusual, so particular pains were taken to make the intent of the specification unmistakable.

CLEARING.—The price bid for clearing on this line will be understood to apply only to the densest, heaviest and most expensive clearing on the line. All clearing requiring less work and expense shall be rated by the engineer.

Thus, if in the judgment of the engineer the work and expense necessary to clear a certain acre of right of way is only one-fourth as much as that necessary to clear one acre of the densest and heaviest timber, then that certain acre shall be entered on the contractor's clearing account as ¼ of an acre.

In what way the writer would ask is the dignity or usefulness of the specification impaired by the last clause? W. D. Taylor.

Madison, Wis., March 18, 1904.

Why the Corps of Engineers of the U. S. Army Should Retain Control of River and Harbor Improvements.

Sir: As an officer of the Corps of Engineers, I would like to say a word or two in reply to the letter signed "Commerce," in your issue of March 24, 1904.

The main part of the "Civil Works" of the Corps of Engineers consist of river and harbor improvements. To the writer it has always seemed peculiarly fitting that the

improvement and the military defense of our navigable channels should be in the same hands. The two subjects should always be considered together; a location for an improved channel, considered purely from the civil engineer's standpoint, might readily make an effective defense of a harbor impracticable in the event of war.

The writer also maintains that the employment of Engineer Officers on so-called civil works is not diverting them from their true profession. A good military engineer is a good civil engineer with a military training. In the event of war, military engineers are invariably called upon, on short notice, to inaugurate and carry on all sorts of engineering work in districts subject to military occupation. They are much more efficient, if, in addition to their military training, they have had previous experience on so-called civil works. Civil engineers without the military training, are notably handicapped under such circumstances, even when their experience and ability are beyond question.

It is entirely possible to give a military engineer a broad experience on public works, without in the least interfering with his proper development from a military point of view; indeed, it is the writer's opinion that such experience will improve the military engineer as an officer, especially in a country where, in the event of war, the forces under his command will be largely volunteers. The civil experience gives just the broadening effect needed after the rigid training at West Point, to secure the very maximum of efficiency. The cadets at West Point who graduate high enough to go into the Engineers or the Ordnance Corps, have the fundamental principles of engineering drilled into them with a thoroughness not surpassed anywhere, and equalled probably by no institution in this country, unless it is the Naval Academy at Annapolis. These men are able upon graduation, to read, without difficulty, any manual on engineering or applied science, from the most abstruse treatise, to the simplest monograph. They need only experience to develop into efficient engineers in any branch of work. Without experience, no technical graduate will ever be an engineer of any kind, no matter how thorough his training.

After graduation, the young engineer officers receive a course of instruction at the engineer school of application which develops their knowledge of engineering principles along the lines of the work of the corps, both military and civil. After that, they serve as assistants on actual work, under older officers, and the effort is made to develop them by placing responsibility upon them in proportion to their experience, increasing the burden with an increase of efficiency, until finally the officer is placed in charge of a district. The present shortage of officers has made it impossible for some time to get the best results from this latter part of the young officer's training; we have enough lieutenants, but not enough of the more experienced officers, so that it has been necessary to invest lieutenants with responsibilities that ought to be carried by captains and majors. The maximum strength ever proposed for the Corps of Engineers would not furnish more than one-fourth of the engineer officers who would be required in the event of war. As long as the strength of the corps is kept so far below war requirements, as long as the corps conducts its present so-called civil works with integrity and efficiency, it seems to the writer that it would be very poor policy to curtail its duties in any way. An increase beyond a reasonable war strength, or an increase for the purpose of acquiring control of other civil works than those which we now control is not advocated by the Engineer Corps, nor by any individual officer thereof, so far as the writer is aware. Such a plan might well be opposed on many grounds. But the increase that has been asked for involves no such plan; it will not cost the United States a cent, for civil engineers to perform the duties of the additional officers asked for will cost at least as much as the officers. The Corps of Engineers takes a natural pride in its record in connection with its so-called civil works; it feels that these works are of the first importance to the development of its own maximum efficiency, in both military and civil work. As long as it conducts the civil works economically, it is cheaper for the United States to leave it in control; transferring these works to civil control would not enable the United States to dispense entirely with the military corps, nor to keep it fully employed in time of peace. Yet it would involve a much greater expense for the civil organization—so that the net result would be a less efficient military corps, with a greater total expenditure.

While the Corps of Engineers is not seeking to annex new territory, it is surely justified, in view of its past and present record, in insisting upon an organization adequate to its present responsibilities, and in resisting the transfer of any of those responsibilities from itself or from the War Department.

Very respectfully,
John Stephen Sewell,
Captain, Corps of Engineers.

U. S. Engineers' Office, Washington, D. C.,
March 26, 1904.

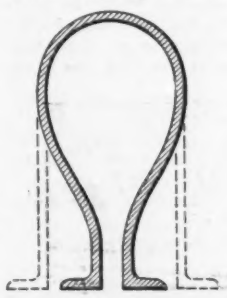
Notes and Queries.

In the report of Capt. John Stephen Sewell to the Chief of Engineers, U. S. A., which was published in our issue of March 24, 1904, an error was made in referring to the thickness of self-supporting brick walls. This thickness was given as 8 ins.; it should be 18 ins.

In the letter entitled "Approving Short Tripods," printed on p. 307 of our last issue an error occurred through a compositor changing the sign for seconds of arc to read inches. It should have read that in only a very few of the triangles observed was the error in closure greater than 3".

In a New York laboratory there was recently tested a piece of trap rock 2 ins. in height and with its top and bottom surfaces 2 ins. square. To the no small surprise of those making the test, the sample withstood a load of 170,300 lbs. before fracture occurred, or showed an average ultimate strength per square inch of 42,500 lbs. This is, we hardly need say, much in excess of the test records of the best granite or in fact of any stone. The only reason that could be found for this very high record was that the sides of the test cubes were left quarry-faced and not polished to a smooth surface in the usual manner. The question arose, therefore, to what extent this should influence the strength of a specimen. We should be pleased to hear from any of our readers who are able to furnish data on this point.

M. A. G., Birmingham, Ala., asks what is the object of constructing the air-chamber of a pump with a small neck, as represented by the full lines in the accompanying sketch. He wishes to know whether the pump would not act equally well if the air-chamber were made as shown by the dotted lines.



Probably the chief reason for building air-chambers with a small neck is a purely mechanical one, to give a convenient connection with the valve-chamber. No reason is apparent why the wide-mouthed chamber, as shown by the dotted lines, would not work as well.

THE WATER USED TO EXTINGUISH the Baltimore conflagration is estimated at 50,000,000 gallons by Mr. Alfred M. Quick, M. Am. Soc. C. E., Chief Engineer of the Baltimore Water Department. Besides the water actually thrown on the flames, it is estimated that about 150,000,000 gallons ran to waste through broken plumbing and service pipes in the burned district.

A DEVICE FOR EASY READING OF TABLES.

Everyone has noticed the difficulty and liability to error in picking out a desired figure from a table of any sort. In reading a table, a selected column and a selected row must be followed to their intersection; not always an easy task, especially when the horizontal rows are long. Many persons habitually use the edge of a sheet of paper as a guide when using tables. A neat mechanical way of doing this appears in an advertising card that reached this office recently. The card bears a table giving capacities of pumps, in gallons per stroke, for various diameters and lengths of stroke. Diameters are listed vertically along the left-hand edge, so that each row corresponds to one diameter. The card is held in a flat case or pocket made of celluloid. A slot cut in the side of this pocket furnishes the horizontal guide, the card being pulled out to bring any desired row under the slot. Besides giving a positive guide across the row, the arrangement also supplies a vertical guide, since the column headings are printed on the outside of the case, just above the slot, and thus the figure to be read out from the table is always brought close under its column heading.

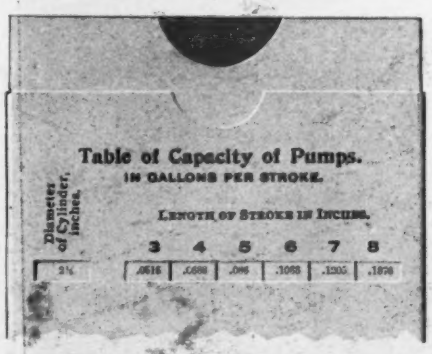


Table of Capacity of Pumps.
IN GALLONS PER STROKE.
Diameter of Cylinder, Inches.
Length of Stroke in Inches.
3 4 5 6 7 8
2½ .0516 .0688 .086 .1032 .1205 .1376

A Device for Easy Reading of Tables.

The accompanying cut, which we have made from the card sent us, shows the device well enough. The card is printed on both sides, and there is a corresponding slot on each side of the case. One side is for lengths of stroke 3 to 8 ins., the other for 12 to 24-in. stroke. The card is issued by the Weinman Machine Works, of Columbus, O., makers of steam pumping machinery. The arrangement is such a convenient scheme for any table to which frequent reference is made that we have thought it worth while to call special attention to it. It will be evident that any draftsman could make in a few minutes from cardboard or stiff paper a similar pocket to hold any table to which he frequently refers.

SOME TESTS ON BRIDGE TIMBER FIFTY-ONE YEARS OLD.*

By Edwin Dwight Graves.†

During the year 1902 the writer served as member of a Committee of the Court, for the purpose of determining the value of an old wooden toll bridge. This commission consisted of one lawyer and two engineers.

Among the interesting points brought out by the testimony was the question of the value of sound timber which had been actually in use in the structure 51 years. Of course decayed timber was condemned at once, but an attempt was made by one of the parties interested to show by testimony that the sound timber was valueless on account of its age. The timber was old growth white pine, of excellent quality. It had been under cover and well protected during these years, and of course was absolutely well seasoned. The testimony of a great number of so-called "practical" men was directly contradictory, depending upon which side called them as "experts." The wood was characterized as "punkey," "wooley," "dosey," "lost its life," "brittle," "dead," etc., according to the views of the different men; and also "as good as ever," etc., by the opposing side; all pure matter of opinion or prejudice.

In order to clear up this radical difference, we determined to make actual tests of this material on samples taken from the top chord, which chord was made up of two pieces 8 × 12 and one piece 10 × 12. Samples from several timbers were selected and sawed up and planed to 1 in. square and 2 ft. long. A number of samples were tested at the laboratory of the Massachusetts Institute of Technology, and others at the laboratory of Henry Souther, of Hartford, Conn., on a 100,000-lb. Seller's machine.

TENSION TEST.—The test pieces for tension were turned down to a section ⅝-in diam., for a length of 2 or 3 ins. at the middle of the test piece.

7 samples at Hartford averaged 8,261 lbs. per sq. in.
6 samples at Boston averaged 8,399 lbs. per sq. in.
Average, 8,330 lbs. per sq. in.

TRANSVERSE TEST.—Tests on bars about 1 in. square, resting upon rotating supports 12 ins. apart, with a load gradually applied at the middle, give the following average calculated stress on the outer fiber at the breaking point, from the following formula:

$$f = \frac{3\,w\,l}{2\,b\,h^2}$$

7 tests at Hartford, 9,200 lbs. per sq. in.
6 tests at Boston, 9,820 lbs. per sq. in.
Average, 9,510 lbs. per sq. in.

The fracture in every case was tough and stringy and showed no signs of brittleness.

COMPRESSION.—Tests for compression endwise the grain were made at both laboratories on samples 1 in. square and 2 ins. long.

4 tests at Boston averaged 5,597 lbs. per sq. in.
2 tests at Hartford averaged 6,050 lbs. per sq. in.
Average, 5,824 lbs. per sq. in.
Weight, 27.96 lbs. per cu. ft.

The American Association of Railway Superintendents of Bridges and Buildings, in Report of Convention of 1895, recommend for the ultimate breaking stresses per square inch for white pine:

Tension with the grain	7,000
Compression with the grain	5,500
Transverse, extreme fiber stress	4,000

In the opinion of the writer, this old timber, when in good condition, is to-day worth as much or more than most of the new timber which could be found to replace it.

*Abstract of a paper read before the Connecticut Society of Civil Engineers.
†Hartford, Conn.

HIGH TENSION OVERHEAD WIRES IN CALIFORNIA CITIES.

The objections to overhead wires in city streets on account of their obstruction to the work of firemen, their danger to life and property, and their ugly appearance, have led in the larger cities to the placing of electric wires in underground

conduits; but in most cities of moderate size very little has been done in this direction. In some of the cities of the Pacific Slope the evils of overhead wires are aggravated by the presence of wires carrying high voltage currents for long distance transmission.

We show herewith a photograph of a street in Sacramento, Cal., taken from a third-story window of the Sacramento "Bee" office, and we are indebted to that journal for the copy of the photograph here reproduced. Concerning the character of this network of wires, the "Bee" said in a recent issue:

This picture does not exaggerate conditions with respect to the high tension wires as they exist on the streets of Sacramento to-day. At almost any point downtown the wires are as numerous; at some points they are even more numerous than in the photograph herewith reproduced.

Many of the wires shown in the accompanying picture are of high voltage. From some of them the insulation has worn so that it is corrugated, or ragged, exposing here and there the bare wire. This condition of the insulation is not peculiar to this section of wire alone; but may be found almost at any point through the city where the wires run. At some points this insulation hangs in shreds from the wires. This condition renders the wires extremely dangerous.

The Grand Jury of 1902 demanded that all these power wires, which are liable to drop at any time, causing death and destruction and presented a letter from Alfred Stillman, Secretary of the Executive Committee of the Board of Fire Underwriters of the Pacific, San Francisco, urging that some action be taken to cure the defects in the wiring system in Sacramento.

Nearly 100 wires can be counted running past The Bee building in different directions. The high voltage appears in the heavier black lines across the face of the picture. As these wires are only a sidewalk's width away from the building, it can readily be seen that they would, in case of fire, stand in the way of the operations of the fire department, if, in fact, they did not imperil the lives of the firemen.

HIGH-TENSION ELECTRIC WIRES ON A BUSINESS STREET IN SACRAMENTO, CAL.

wires be put underground, in conduits, where they would no longer be a menace to life and property. The Grand Jury of 1903, dissolved only a few weeks ago, repeated this demand in even stronger terms. Mayor Hassett, in his inaugural message, early this month, treated at length of the danger which threatens from these high power

TWO SUGGESTIONS FOR EXHAUST STEAM HEATING.

By William E. Wood.*

These suggestions are intended mainly for the engineer in charge of a power house of moderate size, who is called upon to heat certain spaces in the most economical manner with limited resources. It is assumed that there is sufficient exhaust from a non-condensing engine.

The old method of placing a relief valve at the roof, as is still commonly done, is wrong in principle and only permissible in specially high buildings on account of the extra cost of additional riser. With the relief valve at the roof, the heating system has wet steam to work with and the engine is unnecessarily overloaded. The sketch in Fig. 1 shows the improved method which the writer has used with success. The exhaust pipe from the engine is run horizontally to a T in the riser, and at this point the water falls and the steam rises. The lower end of the riser is carried down to the floor line and run to the open air through a weighted back-pressure valve. If it is desired to heat with a maximum of say 2 lbs. per sq. in., the valve is loaded for that amount; then the horizontal pipe from the engine must tap the

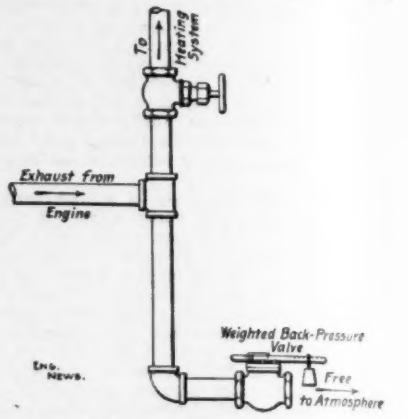


Fig. 1. Connection of Exhaust Pipe to Riser for Steam Heating System.

riser more than 4 ft. above the back-pressure valve. It is evident that the weight of water in the stand-pipe will open the back-pressure valve and drain the riser. The greatest back pressure that can be put on the engine is the amount necessary to blow the water seal if the engine delivery exceeds the condensation in the radiators.

The open air exhaust leads out of the building and properly should rise to the roof with a bleeder at bottom and exhaust head at top, and with no obstructions in line other than the relief valve shown. The main riser to the heating system should go to the highest point in building and branch off, coming down to the radiators. The drips should all center at the boiler room into the receiver of a combined pump and receiver, where the hot water will be automatically returned to the boiler. The returns must be joined under water, otherwise a rattling sound will result.

For the radiating surface, pipe coils or cast-iron radiators can be used. If pipe coils, care must be taken to allow for expansion by turning a corner of the room or by feeding into a branch tee placed horizontally, which makes an upright turn and gives spring to the coil. The great trouble with coil heating is making the coils too long. Such coils fail to heat at the drip end under low pressure, and the usual course is to raise the pressure and force the circulation, with resulting noise and overload at engine. With labor considered, the coils really cost about as much as cast-iron radiators, which can be placed at convenient points and removed easily if so desired. In selecting radiators, it is to be remembered that the standard height (38 or 39 ins.) will cost less per sq. ft. than low radiators. In certain cases, however, the low radiators are better and should be used.

While there are scientific methods for proportioning radiating surface, the average case in a factory can be better judged on its merits. If there is a little too much, part can be shut off, while the place will be cold if there is insufficient radiation. The use to which the room is to be put, as well as its exposure and construction, will all have a bearing on the question, but in a general way it will be found that 1 sq. ft. of steam radiation is sufficient for 50 or 60 cu. ft. of space in an office. Shops will demand only 1 to 80 or 1 to 100, unless the operators are inactive and seated at window benches, when in some cases they may require office rating. This is intended for well constructed buildings with normal exposures; any unusual amount of glass or wind exposure will demand more surface. The radiators should be placed in the cold part of the room. Sometimes excellent results are attained in exhaust work by using hot-water radiation, which, being connected top and bottom, circulates very freely.

When the engineer of a plant of moderate size

*Consulting Engineer, James B. Clow & Sons, Chicago.

has his exhaust system in proper shape he will need to provide for some heat at the time the engine may be idle. This will require the use of live steam and a valve for reducing the pressure. There are many excellent reducing valves on the market, but care must be exercised in the selection or trouble will result, and it is desired to show here that a satisfactory combination can be made from regular stock material. The arrangement proposed, and used by the writer, is shown in Fig. 2.

The steam with full boiler pressure enters a balanced valve, which is of the double-seated or double-port piston type. If of the double-seat type, it is so arranged that the steam enters at the end leading between the disks, otherwise the steam will act on two circles of different areas and the action will be irregular. An ordinary balanced valve turned upside down will do the work. From this valve the steam is run into the low-pressure heating main, reducing to say 1 or 2 lbs. pressure. At some convenient point a T is set in the main with branch on the bottom for a drop pipe of about 1½ ins. diameter, which will act as a water pocket and stiffen the regulator

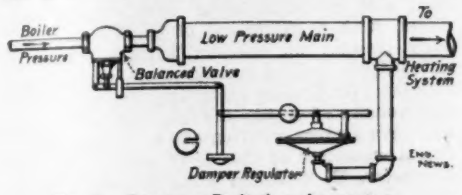


Fig. 2. Pressure Reducing Apparatus.

support. This leads to an ordinary low-pressure damper regulator, as shown, and the regulator and balance valve levers are connected by links, as shown. The regulator is one that is used on every low-pressure house-heating boiler; it is cheap, always at hand, and sure in operation.

Directly under the link connection is attached a weight holder for small split weights, which can be used to increase the low pressure. A balancing ball weight can be used on the lever of regulator to secure proper action. It is well to have a low-pressure steam gage attached, as it will aid in setting the regulator, and show that it remains in adjustment. If 1½ lbs. exhaust pressure is carried, and the reducing valve is set at 1 lb., the latter will not act when the former supplies the demand, but when the engine is shut down and heating pressure falls below 2 lbs. the reducing valve will open and continue to supply steam until the engine takes up the duty again.

A good stop valve must be put on the boiler pipe before it enters the balanced valve, and if a globe valve is used it must be placed with its stem horizontal. This is sometimes overlooked, with the result that the line is pocketed. It may be advisable to attach a safety valve to the low-pressure line, as it would give warning. The element of danger, however, is remote, as the rubber in the regulator would be an excellent safeguard. This combination has been successfully used for years. There are no needle valves to plug up, and it is simple and effective.

RECLAMATION OF THE MARSHES OF NEW JERSEY AND STATEN ISLAND.

By Henry Clay Weeks.*

The average value of a square foot of land on the island of Manhattan is more than the average value of an acre in the undrained and pest-bearing marshes just over the eastern borders of New Jersey, only a few minutes' travel distant. This striking difference exists because in the marshes we find about the worst conditions that can be imposed upon real estate. The section itself is practically uninhabitable, and never will be habitable until it is drained. Moreover, it produces conditions of unhealthfulness and consequent depression of property values which affect a vast contiguous territory.

About 40,000 acres of land in these marshes are substantially at high water level or so little above the normal tides as to be flooded by any extra high tides. A direct result of this saturation is the nuisance of mosquitoes and mosquito conditions—a conceded menace now to life, health and vital energy as they have always been conceded to be to land values, and to comfort of man and beast. The proper drainage of this great territory means the opportunity of draining the fresh water breeding places of the Anopheles mosquito, which is the only proven source of malaria, and that means more to this section than can be expressed in figures.

This now has become a case where the Departments of Health of the cities and states involved and the Public Health Service of the general government should co-operate to put an end to a condition which directly affects the health of a vast territory, thereby lessening the value of labor as well as of property, which drives away population, thus lessening commerce, is offensive to the eye and to the sense of smell, and, indeed, constitutes a national nuisance.

The necessity for the solution of this problem has for many generations been pressed with great insistency upon the attention of the people of a large section about the Metropolis, and, indeed, upon all who have ever passed through these extended wastes; but, although the subject of most elaborate engineering, commercial and economic investigation, it still remains unsolved.

It is not necessary here to recount the many plans, nor the regularly recurring prospectuses which have held out hope that these marshes would be redeemed. The one study of the case, which of all others should be referred to on account of the careful detail with which it was considered and presented, is that made by Mr. C. C. Vermeule, Consulting Engineer, and submitted to the State of New Jersey by its Geologist in his reports for the years 1896 and 1897. Mr. Vermeule's argument on the necessity of reclamation from the commercial and sanitary-economic standpoint is unanswerable, and the indorsement of Prof. John C. Smock, State Geologist, is equally strong. And this report of Mr. Vermeule was made before the positive knowledge which now exists of the spread of malaria from a certain kind of mosquito.

While it is a fact that New Jersey has the greater interest in this matter, it is equally true that the menace of these great marshes is against the people of New York almost, if not absolutely, as much as against the people of New Jersey.

The problem therefore is one which belongs not to New Jersey alone, not only by virtue of interest, but because of the added fact that a large area of the so-called "Jersey marshes" are actually in New York State, and even within the limits of New York City, in its Borough of Richmond. Nearly the whole western side of that borough is in a condition quite as unhealthy and troublesome as the New Jersey marshes. In all there are over 40,000 acres of land involved in the stretch of about 35 miles from above Hackensack to Perth Amboy, and 13 miles of the distance border the Borough of Richmond. It is considered safe to say that the suggestions made hereinafter would also affect the swamps in the towns of Washington and Harrington, 12 miles further north of Hackensack, and even those above the New York State line.

PREVIOUS PLANS FOR RECLAMATION.—All the remedies which have been suggested, or at least all those noted by the writer, in extensive reading on the subject, have proceeded on the assumption that there are only three ways to meet the difficulty: (1) To elevate the marsh land by material taken from canals throughout the marsh; (2) to effect the same elevation by filling with material procured elsewhere; (3) the carefully considered plan of Mr. Vermeule, which contemplates protection against the tides by elevating the present shores of water courses by the ordinary method of diking and then draining interior parts through dikes with automatic tide gates emptying at low tide.

Figures show the financial difficulty of two of these plans, which is aside from the consideration that the work would take many years to accomplish. The results in all three cases would be incomplete, for the land would be unfitted for residence, not only on account of there being no provision for continuous disposal of sewage, but, by reason of percolation and saturation, water would stand too near the surface. For the same reason cultivation of the land would not be the most successful without much pumping.

(1) The plan to open canals all through these 40,000 acres and using the materials for elevating other parts would cost over $25,000,000, on the basis of Mr. Vermeule's data.

(2) It would take to properly fill the whole area about 300,000,000 cubic yards of soil; and to purchase (probably), transport, grade and drain same would cost about $150,000,000.

(3) To raise dikes and do necessary preliminary work would cost, according to the moderate estimate of Mr. Vermeule, at $100 per acre, $4,000,000; his estimate of maintenance and pumping of $5 per acre per annum is also a moderate figure, and yet involves $200,000 per year for all time. This vast area was once a great bay, with a depth of water in some places of over 20 feet. As the marsh formed here by accretion will dry out when reclaimed, it will shrink and settle, and thus cause the proposed gates to become inoperative. Hence, after a few years resort must be had entirely to pumping the rainfall out of the embanked areas, or to filling. Indeed, pumping would have to be resorted to from the first in some instances where the marsh level is unusually low.

Though it is some years since the plan of Mr. Vermeule was proposed, it is still unexecuted, and it is acknowledged to be largely because of the inherent difficulty presented in the hundreds of owners throughout the area and of its varied municipal or town control as well as the difficulty of apportioning the cost. The interests are too many to harmonize, though such harmony is a remote possibility. But the question is, if such harmony could be secured, are the results the best that could be had?

ESSENTIAL CONDITIONS TO BE MET.

Any plan for the reclamation of these marshes must satisfy certain essential conditions or it cannot be considered, no matter what its merit in other respects may be.

In the first place it must not injure navigation. Diverse statements are made respecting the magnitude of the navigation interests. The largest estimate is that 15,000,000 tons of freight per annum pass through the waterways connecting these marshes with New York Bay. (See accompanying map.) Again, an improvement must be so planned that the waters affected shall not become any more impure than they will be under the operation of the sewerage plans now under way. The cost must not be prohibitive, nor the difficulty of distributing the cost to the property affected such as to make it impossible to operate the plan. The inefficiency of work in sections needs no elaboration. The problem must be treated as a whole to reach satisfactory results.

It is believed, however, that a workable plan may be suggested which will redeem the whole situation, and which will have none of these or other insurmountable objections.

The writer, referring to this question, at the 28th annual meeting of the New Jersey State Sanitary Association at Lakewood, Oct. 24, 25, 1902, said:

> The speaker has long had in mind some relief plans which he has not had the opportunity or time to confirm by data, which have not been suggested, so far as he has noticed. Some such plan would seem to solve the difficulty. Surely advanced thought must find some way of overcoming the great evil to values, to health, to appearances, which prevail in this great waste area.

THE PROPOSED PLAN OF IMPROVEMENT.

Those who have studied this subject will doubtless agree that the simple making of ditches will not effect complete reclamation unless there is *continual* drainage. The surface of valuable land, situated as this is, must always be kept several feet above the high water level in bordering streams or ditches to get most comprehensive results. This may be accomplished by lowering the streams bordering and traversing these marshes, and in that idea lies the difference of the plan to be described from the diking system, heretofore considered the only one commercially practicable. I propose to explain how this may be done at two strategic points, and then answer anticipated objections which may be made to the general idea.

The plan contemplates constructions at two points only to reach the object sought, namely, (1) at or about on a line from Tottenville to Perth

*Bayside, Long Island, New York City.

Amboy; and (2) from Port Richmond to Bergen Point. These controlling works would consist at both places of dams, in all about 3,000 ft. long, provided with suitable gates, which would prevent the high tides from flowing into the Arthur Kill and the Kill von Kull. These gates would be opened when the outer water is at a tide level lower than the nearly constant inner level. This latter level will be normally but slightly affected by water which has accumulated between low tides, since the area of Newark Bay is very large compared with the flow in the streams entering it. The gates would be so made as to permit locking vessels through the dams and the gates would stand entirely open for a period before and after the lowest ebb tide. When the tide begins to flow in the outer gates will be closed, holding the inner waters at a level a little above low tide, as before implied.

This plan, as briefly stated, would lower and maintain the height of the water within the structure for the whole 40 miles of water course to a little above low tide at all times, preventing the high tide from causing any substantial rise within them. That would mean the equivalent of a filling in of the entire inner marsh area to a depth of about 4 ft. 6 ins., and hence would result in an opportunity of thoroughly draining the entire marsh. It would accomplish by engineering work at two points what would otherwise require diking or filling in over the entire marsh area. It would make cultivation of, and even the erection of buildings on, the entire area possible.

OBJECTIONS.

Objection 1. Probably the first objection that would occur to one would be that such constructions would obstruct navigation.

It is to be remembered, however, that practically nothing but freight traffic is involved here, and slight delays to pass locks will not be serious. That locks are not considered any bar to navigation, where they are necessary to secure important ends, is seen in the fact that there is more traffic through the locks at the Sault Ste. Marie than through the Suez Canal, or even than the entire traffic of Liverpool, the most active port in the world. Further, twice in every 24 hours the gates may be opened for free movement of vessels in or out for a total of about five hours, namely, before and after the lowest ebb tide, when the water each side of the locks is about the same height.

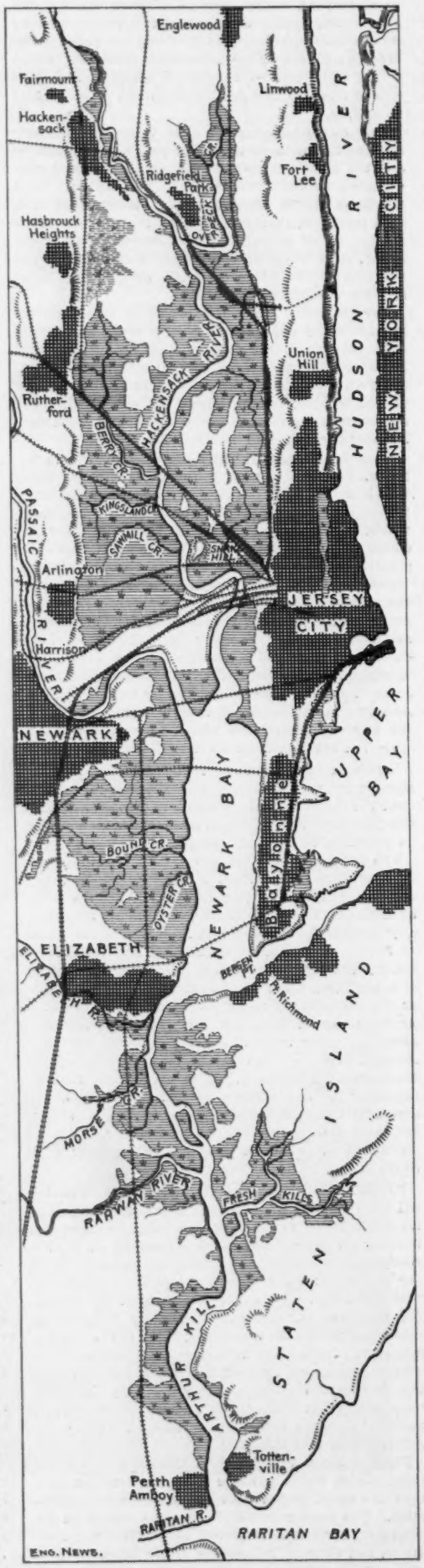
It will be recalled that Haarlem Mere was once navigable, but by that great reclamation it was given up as a waterway to effect vaster results. The same law should apply here. The greatest good to the greatest number should be the controlling idea.

Objection 2. The next objection is, that, by maintaining the inner water level at about low tide, vessels of deep draft might not be continuously accommodated.

In answer to this it is to be explained that there is provided for, by government appropriations, a depth of waterways fixed upon by various interests as sufficient—of 21 ft. in a channel between Upper New York Bay and Raritan Bay, which channel will circle Staten Island on the north and west; a channel depth of 10 ft. in Newark Bay and thence up to Newark; and a depth of 8 ft. thence to the city of Passaic; and that these depths are at *mean low tide*. The present plan is merely to keep the inner water a little above mean low tide so that the continuous conditions of navigation for vessels of maximum draft would be benefited rather than injured by the present plan.

If greater depth is ever needed than that for which provision is already made by the government, as above stated, these works would not interfere, for the locks could be built for vessels of any reasonable draft.

Objection 3. Another objection is the cost. An approximate estimate places the cost at less than that for any plan proposed. However, no test of the character of the bottom has been made, nor of the foundation depths, hence there has been no more than a mere approximation of costs. There are, however, but two points where comparatively short channels are to be spanned with dams in all about 3,000 ft. long, and these dams can readily be made into causeways for vehicles or railways, or both, the rental of which would help pay for their cost. The expense of cross-ditching in the meadows is necessary in any case, but will be much less than by any other plan.



Map of the Marshes Adjacent to Newark Bay and the Staten Island Kills.

Objection 4. The difficulty of bringing about necessary action may be urged by some. But if such objectors had the experience of trying to bring unanimity in even a small reclamation where a few owners were involved, they would see in the present suggestion a very simple proposition, as compared with the other plans for reclaiming these great areas. By the present plan probably only the general government, the sister states and New York City would be required to act.

Objection 5. There is an objection which may be made by some who have not studied the conditions as they compare them with situations where such objections might be of some force, that is, that by the restraining of the tidal inflow and outflow their effect in scouring of channels would be lost.

In answering this, let it be recalled that though, by the plans as explained, there will be a comparatively slight inflow, there will be a strong outward current, tending to keep the channel open, and there will be no sediment brought in twice a day by a strong inflow, as at present. It must also be remembered that several large rivers, with a catchment of 800,000 acres and daily pouring an ordinary average volume of 1,280,000,000 gallons through these channels, are inclosed within these controlling works, and that this volume of water, always moving one way, will have a great scouring effect. In this connection a statement of Col. J. W. Barlow, Corps of Engineers, U. S. A., in a report dated Jan. 25, 1900, to Brig.-Gen. John M. Wilson, Chief of Engineers, is very encouraging. This report was approved by Secretary of War Root, and later resulted in an appropriation by the general government of $696,000 to improve these channels:

> It is believed that the proposed improvement is of a permanent nature, and will require only a small expenditure for maintenance, as there are no silt-bearing tributaries, the shoals are not sedimentary deposits and there are no shifting sand bars.

A report of Major Adams, U. S. A., in 1896, stated that at the end of about 20 years the Arthur Kill channel retains practically the full depth, reduced somewhat by washing in of material from the adjacent flats.

If, however, any shoaling should occur contrary to the above ideas, it could be readily corrected. It is hardly supposable that the expense for dredging can be as great after as before the proposed works are constructed.

Objection 6. An objection naturally following the last is that the pollution of the river would not be as thoroughly counteracted through the lack of incoming salt water, held back by the proposed dams and gates.

In answering this, it is not necesary to assume what is a fair assumption, that these waters should not be polluted. When the plans now under way are carried out and possibly more stringent measures taken to prevent pollution, the great volume of water in Newark Bay will be comparatively pure. By opening the locks herein proposed and other gates before low tide, a great volume of salt water will enter and aid in making and keeping still more pure conditions; and then when the tide is lowest there will be a strong outflow which will clear out all impurities that may have collected. This purification may be aided by the gate valves along the bottom of the entire dam, as above noted, which could be opened, as well as the locks, when the inner water was higher, so as to let off any accumulations along the bottom of the dam at the sides of locks.

Objection 7. When there is a concurrence of a very high tide, and a very heavy rainfall, is there not a rare possibility, which should be considered, of the water rising, as it does now, above the inner bank and flooding works and areas not provided against such an emergency, before the falling tide allows escape of the accumulated water?

To this answer may be made that there is a natural reservoir within the dams for such an emergency, which consists of over 10,000 acres, and that in it there would be the opportunity of accumulating water if necessary to a depth of about 4 ft. without damage.

Assuming the estimate kindly furnished by Mr. H. B. Kummel, State Geologist of New Jersey, through Mr. C. C. Vermeule, of that state's catch-

ment area emptying through the two kills north and west of Staten Island as 1,251.4 square miles, and the greatest flood flow under the most unusual conditions to be 18,020,000,000 gallons in 24 hours, and that the proposed controlling works under such conditions would be closed about eight hours at one time, we have a most rare possibility of requiring storage for 6,000,000,000 gallons above the low level. An approximation of the storage capacity in Newark Bay and in all the rivers and creeks for each foot of depth is 4,000,000,000 gallons, so that the greatest supposable rise of the water in the inclosed area would be 1½ ft.

Objection 8. After ten years or so by subsidence of the marsh, would extensive dredging not be necessary to preserve the depths of channels now provided for by the government?

This may be answered by a statement of fact that the banks of the streams would settle on account of their saturation but little as compared with the interior. If some dredging were necessary to preserve the full depth it would doubtless be very much less than under any other system of reclamation, for reasons referred to above. Provision at the locks for deepening of the channels could be made in their construction, even to the extent of the fullest subsidence.

Of course, if the interior water were ever required to be kept below low tide, pumping would have to be resorted to, as is done in many other situations. But this contingency is considered very remote.

Objection 9. The argument against a construction across the stream as liable to result in accident could be met by a reference to the case of the foreign situations, where exposure to the open sea affords much greater chance of accident; and further that provision against accident may be had by extra or emergency gates.

Objection 10. Would domestic drainage be hindered by the proposed works?

Mr. Vermeule, who is as familiar with the conditions as any engineer, says:

> An additional reason for adopting a lowering of the water level (by his plan) rather than by raising of the land is found in the fact that some districts already built upon in the eastern part of Newark have defective drainage. To raise the meadow land would aggravate the evil, while lowering the water level will greatly improve the drainage of considerable areas at the present city.

The present plan lowers the level by keeping out the flood tide, as explained, and not by diking, and by many tide gates, and afterwards by pumping.

I close with a comparison of the valuation of these 45,000 acres directly affected by the foregoing recommendations (not mentioning four times as many more indirectly), whose valuation may be fairly averaged as $10 per acre, with a tract three miles distant of 13,487 acres, including parks, streets, and all exempted property, whose taxable valuation in 1903 was $3,483,000,000, and is doubtless worth as an investment $5,000,000,000—say 40,000 times as much as the former.

Thus do mosquitoes and mosquito conditions affect other considerations besides public health, and these two are by no means all that are affected. The problem is one of the most far reaching before the country or the world.

THE FIVE DAMS AND WOOD STAVE CONDUIT OF THE SOUTHERN CALIFORNIA MOUNTAIN WATER CO.

(With full-page plate.)

In the extreme southwestern corner of the United States the Southern California Mountain Water Co. is developing one of the most notable water supply systems in the world. The company has already built three dams of unusual design, has had two incomplete dams in use for a number of years, and has built a portion of a 20-mile wood stave pipe line, 42 and 36 ins. in diameter, which is under a maximum head of 391 ft. Of the two incomplete dams, work on one (the Moreno), was not stopped until the 100-ft. reservoir contour had been reached, while the other, temporarily stopped at a height of 35 ft., is about to be completed. This great system will supply water for both domestic purposes and irrigation. Its scene of operation is adjacent to the famous Sweetwater Dam and water system, owned by the Sweetwater Water Co.

The moving spirit in the work of the Southern California Water Co. is Mr. E. S. Babcock, its President. Mr. H. N. Savage, M. Am. Soc, C. E., of National City, Cal., has been Consulting Engineer of the Southern California Mountain Water Co. since 1893, and Chief Engineer of the Sweetwater Water Co. since 1890. We are indebted to Mr. Savage for most of the information and illustrations here given.

The accompanying map, Fig. 1, shows the location of the five dams and the conduit described and illustrated herewith, as well as the location of the Sweetwater Dam, the City of San Diego and nearby communities.

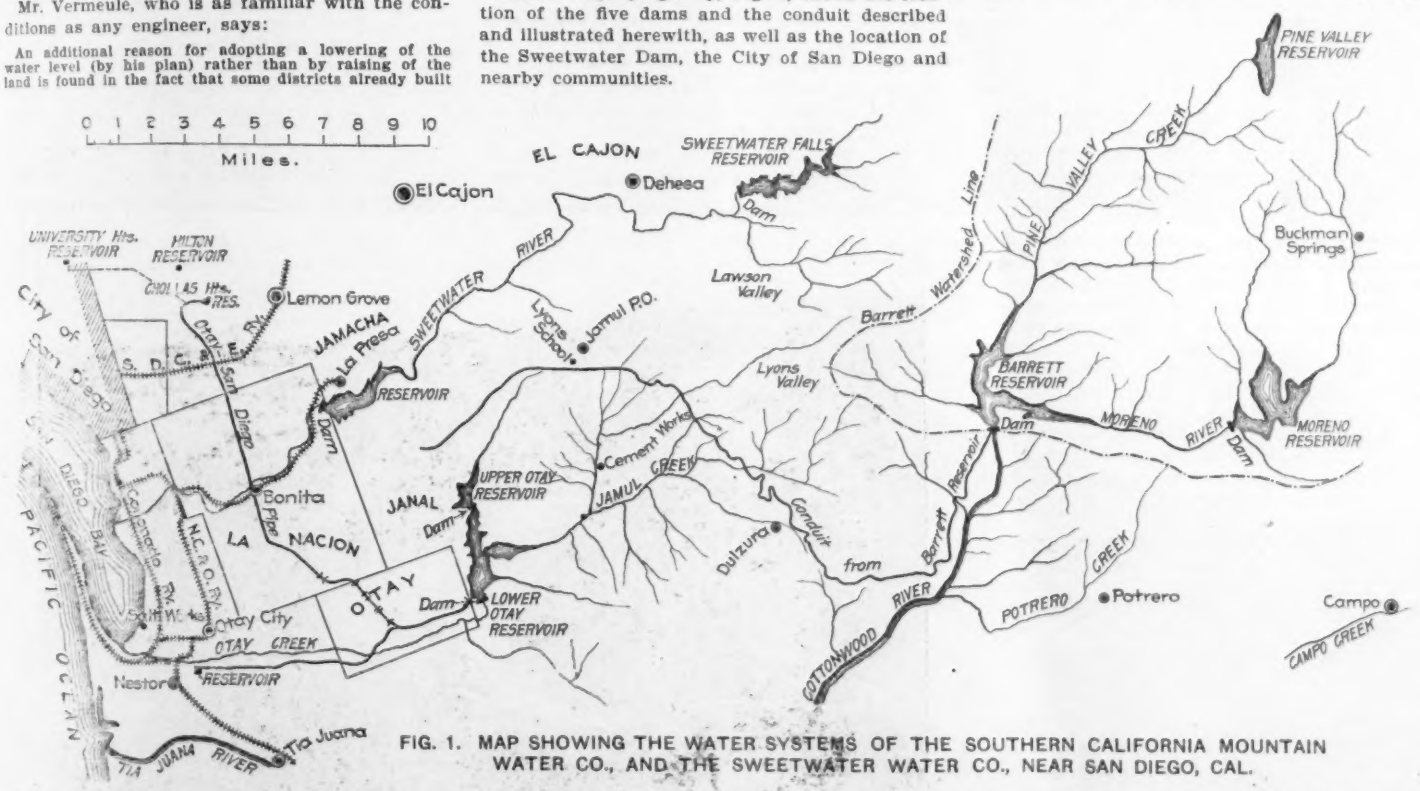


FIG. 1. MAP SHOWING THE WATER SYSTEMS OF THE SOUTHERN CALIFORNIA MOUNTAIN WATER CO., AND THE SWEETWATER WATER CO., NEAR SAN DIEGO, CAL.

Of the five dams, the Moreno is a rock-fill structure; the Lower Otay is a rock-fill dam with a steel core plate; the Upper Otay is of concrete, with steel plates and cables embedded in its center; the Chollas Heights is of earth, with a steel core plate for part of its height; and the Barrett, although originally projected as a rock-fill dam, will be a rubble masonry structure. None of the reservoirs has yet been completely filled, the rainfall having been low since they were built. In fact, there has been practically no run-off in the adjoining Sweetwater drainage area for several years past, nearly all the water for irrigation under the Sweetwater system meanwhile having been pumped from wells, located chiefly in the valley of the Sweetwater River.

The Moreno dam is about 60 miles from San Diego and some 3,200 ft. above the Pacific Ocean. At about one-half the elevation named and eight to ten miles or so nearer the city is the Barrett dam. The upper and the lower Otay dams are 550 and 400 ft. above and 20 and 22 miles, respectively, from San Diego. The Chollas Heights dam is only four miles from San Diego.

Water from the Moreno reservoir flows down a natural channel for eight to ten miles to Barrett reservoir, From the latter a conduit is projected,* as shown on the map, to Dulzura, a point on one of the headwaters of the Otay River, thus giving a natural connection with the Lower Otay reservoir. From this reservoir a conduit 20 miles long, 8½ miles of which are already completed, will lead to San Diego.

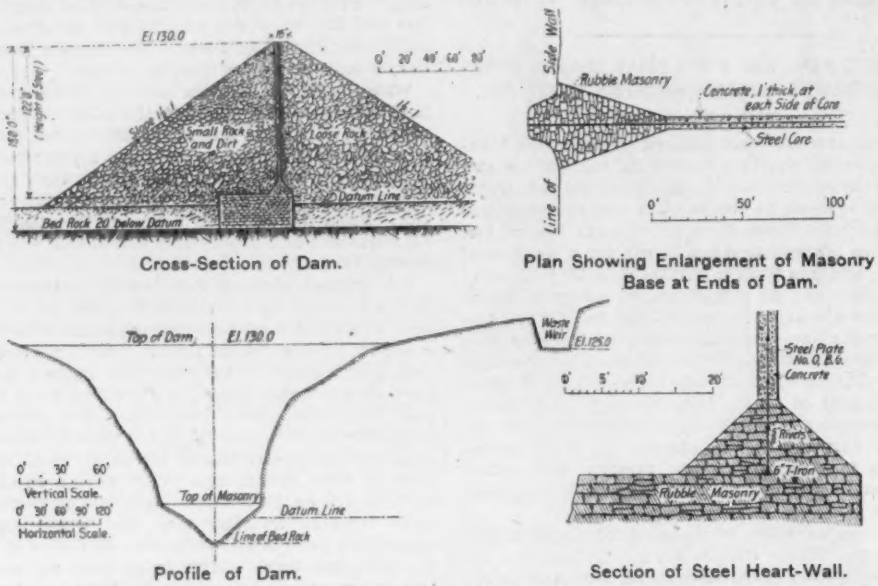
The conduit between the Barrett reservoir and Dulzura would have a capacity of 200 cu. ft. per sec. Preliminary surveys and estimates have been made for a cement-lined trench, a wood stave conduit, and a chain of tunnels. The tunnels would have an aggregate length of 8¼ miles; wood conduit, 11¼ miles; canal, 11¼ miles. The projected irrigation-power conduit line (Fig. 1) running from Dulzura to San Miguel Mt. would be 25 miles long, of wood staves, and would have a capacity of 75 to 125 cu. ft. per sec. It would command a large tract of irrigable land and would afford power at a head of 500 ft. and an elevation of 600 ft. above sea level. After being used for power this water would be available for irrigation in the vicinity, or could be delivered into either one of the Otay reservoirs, or into the Sweetwater reservoir.

The foregoing is only an outline of the completed and particularly of the projected works of the Southern California Mountain Water Co. Other reservoirs and pipe lines are projected, and the company owns the Jamul and Janal ranches, with a combined area of over 13,000 acres, besides having contract rights from the San Diego Land & Town Co. to thousands of acres in the Otay and National grants, and a contract with San Diego to supply the city with water. The whole domestic water supply of San Diego, it may be added, is now dependent upon water pumped from the bed of the San Diego River and a portion of the year

*Pending the construction of this conduit the water in the Moreno and Barrett reservoirs is not available.

on reservoir stored water brought by gravity from the same stream by the San Diego Flume Co.

The five dams will now be described, as nearly as may be in chronological order, after which some details of the wood stave conduit will be given. Views of the several dams are presented on the full-page plate accompanying this issue, and reproductions of line drawings are printed in the text.*



Cross-Section of Dam.

Plan Showing Enlargement of Masonry Base at Ends of Dam.

Profile of Dam.

Section of Steel Heart-Wall.

FIG. 2. PROFILE AND SECTIONS OF LOWER OTAY ROCK FILL DAM, WITH STEEL CORE PLATE.

LOWER OTAY DAM.—This dam was begun in 1893 and finished in August, 1897. It was started as a masonry structure 65 ft. thick at the base, but after it had been carried up to a height of 28 ft. above the base and 8 ft. above the bed of the stream the design was changed from rubble masonry to rockfill, with a riveted steel core plate. The dimensions and details of this dam are shown by Fig. 2, reproduced from our issue of March 10, 1898, and Fig. 3, on the full-page plate, is a view of the structure, taken in December, 1901, four years after its completion. The T-iron at the base of the core plate was anchored to the old masonry by means of 1-in. iron bolts, leaded into holes drilled in the stone. The steel core plate has a thickness of No. 0 to No. 3, Birmingham gage, or 0.34 to 0.259 ins. It is protected on either side by 18 ins. of sand concrete. An outlet tunnel 4 ft. sq. and 1,100 ft. long leads to the valley of the Otay River. For further particulars of design the detailed description already mentioned may be seen. The reservoir formed by this dam, when filled to the 130-ft. contour, has a capacity of 42,000 acre-feet, or about 14,000,000,000 gallons. It has a drainage area of about 100 sq. miles. Mr. W. S. Russell was the engineer directly in charge of this dam.

MORENO DAM.—This structure was begun in July, 1896, and after being carried up 100 ft. of its proposed height construction was temporarily suspended in 1897, on account of litigation over water bonds issued by the city of San Diego, with which city the company has contract relations. As designed, the dam was to have been built high enough to impound water to the 150-ft. contour, thus giving a storage of 47,000 acre-ft., or more than 15,000,000,000 gallons. The dam is located in a canyon 80 ft. wide at the bed of the stream, with sides steeper than 1 to 1 for a height of more than 500 ft. Excavation of the foundations of the dam showed a remarkable fissure, Fig. 9, extending to a depth of 112½. This was filled with concrete, and the latter was carried to the 30-ft. contour, thus making a concrete wall 142½ ft. high. Aside from this concrete wall the dam is composed of rockfill, most of which was blown into place by means of three huge blasts, in which 250,000 lbs. of powder were used. It is estimated that each pound of powder moved a cubic yard of rock, and that some of the pieces thus moved weighed hundreds if not thousands of tons. Small pieces of rock were moved from quarries by means of Lidgerwood cables 400 ft. above the bottom of the canyon. An outlet tunnel 8 ft. sq. and 600 ft. long has been built here. The drainage area of this reservoir is 130 sq. miles, at an elevation of 3,200 to 6,000 ft. Fig. 4, on the plate, is from a photograph taken in August, 1900, after the dam had been built some three years.

UPPER OTAY DAM.—This bold steel reinforced concrete dam, of the arched type, is only 14 ft. thick at its lowest point, which is 84 ft. below the top, and also coincides with the natural bed of the creek. The dam is 350 ft. long on top, and for its height lays claim to first rank in minimum section and cost. Two tiers of steel plates, shown in Fig. 10, were placed longitudinally at the axis of the dam, presumably for water-tightness, while above these, at intervals of 2 ft. vertically, a 1¼-in. railway cable was placed, the highest cable being within 5 ft. of the top of the dam. The richness of the concrete increases towards the base, in three stages, as given on Fig. 10. Fig. 11 is a view of the dam under construction, and Fig. 5, on the plate, shows the structure as it appeared in September, 1901, about a year after its completion. The reservoir has a storage capacity of nearly 2,000 acre-feet, or some 650,000,000 gallons, and is to be filled by a conduit from one of the higher reservoirs. Mr. C. M. Bose was engineer in charge of this structure, but the design, or at least its general features, is attributed to Mr. Babcock.

CHOLLAS HEIGHTS DAM.—It is interesting to note that this earth dam, with a ¼-in. steel core plate in its lower part (Fig. 12), was built from June to September, 1901, thus anticipating by some months the use of steel core plates in earth dams, suggested editorially in Engineering News of Feb. 20, 1902.

Fig. 12 shows the details of this dam, and Fig. 5, on the plate, is reproduced from a photograph taken in 1901. The dam is located four miles from San Diego (Fig. 1), on the line of the wood stave conduit from the Lower Otay Dam to the city. It is 56 ft. high above its lowest point, and 326 ft. long on top, and forms a reservoir with a capacity of 150,000,000 gallons, which is said to be sufficient to supply the present wants of the waterworks of San Diego for about 30 days. Mr. E. F. Tabor was the engineer in charge of this dam.

THE BARRETT DAM.—Designs (Fig. 13) for completing the Barrett Dam as a masonry structure have been made by Mr. Savage and accepted by the company, and a construction plant, including two lateral-movement 20-ton Lidgerwood cableways was assembled some months ago, but nothing has been done since. This dam was built to a height of 35 ft., 13 ft. thick at the top, and a top length of 150 ft. in 1897. When built to a height of 175 ft. above its lowest point the reservoir above the dam would have a capacity of 48,000 acre-feet, or some 16,000,000,000 gallons. The reservoir has an independent drainage area of 120 sq. miles, besides commanding the 130 miles tributary to the Moreno reservoir. An outlet tunnel 8 × 8½ ft. in section and 800 ft. long has already been built.

Figs. 7 and 8 show the dam as built to the 35-ft. level, and are from photographs taken in May, 1900. It was proposed for some time to continue this dam as a rock fill structure with a steel core plate, but, as indicated by Fig. 13, masonry consisting of large rock embedded in concrete will be used instead.

THE WOOD STAVE PIPE LINE.—The 42 and 36-in. pipe line mentioned several times in the preceding portion of this article will have a length of 20 miles. On this 8½ miles have been under continuous pressure since Aug. 12, 1901, the maximum head being 293 ft. For the higher pressure the staves were dressed from 3 × 6-in. redwood. The proper size of bands not being available, some bands only ½-in. in diameter were used, and where the pipe was under maximum pressure the bands were 1 in. c. to c., making it necessary to deflect

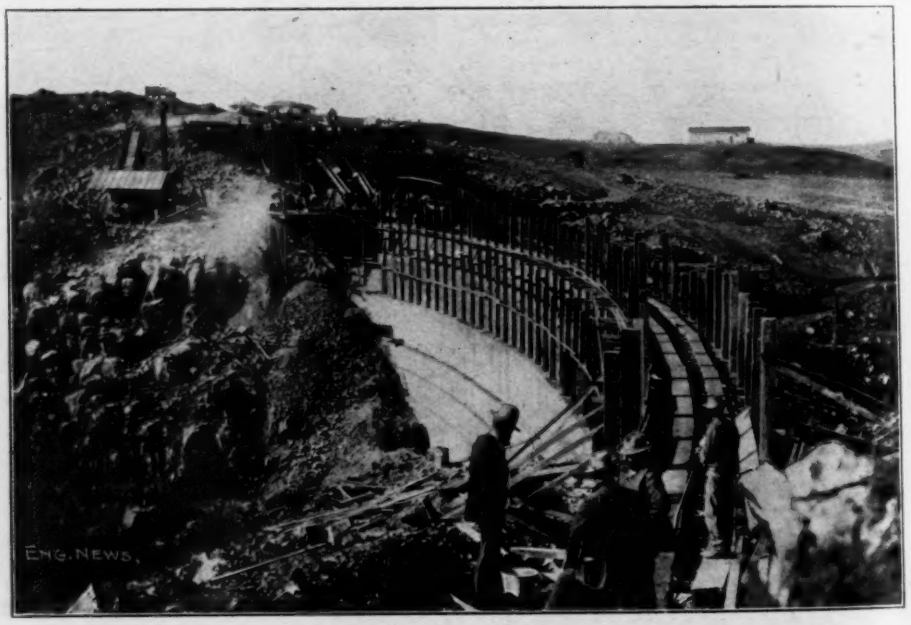


FIG. 11. VIEW OF UPPER OTAY CONCRETE DAM UNDER CONSTRUCTION.

*The Lower Otay dam was fully described and illustrated in our issue of March 10, 1898; the Moreno and Barrett dams, so far as built, and the Upper Otay dam were briefly described, but without illustrations, in our issue of Aug. 22, 1901. For convenience some of the illustrations of the Lower Otay dam and most of the text hitherto published are repeated to accompany the new matter here given.

FIG. 4. MORENO ROCK FILL DAM, WITH CONCRETE WALL AT BASE.

FIG. 5. UPPER OTAY CONCRETE DAM, WITH STEEL PLATES AND CABLES AT AXIS.

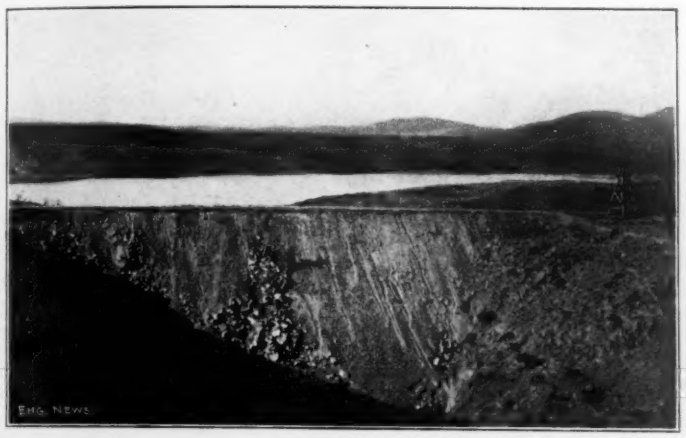


FIG. 3. LOWER OTAY ROCK FILL DAM, WITH STEEL CORE PLATE RESTING ON MASONRY WALL.

FIG. 6. CHOLLAS HEIGHTS EARTH DAM, WITH STEEL CORE PLATE AND CONCRETE WALL AT BASE.

FIGS. 7 AND 8. FIRST STAGE OF BARRETT MASONRY DAM, FROM ABOVE AND BELOW, MAY, 1900.

THE FIVE DAMS OF THE SOUTHERN CALIFORNIA MOUNTAIN WATER COMPANY

E. S. Babcock, President; H. N. Savage, Consulting Engineer, National City, Cal.

each band around the connecting saddle of the adjacent band. Fig. 14 is a view of this conduit where it is under a head of 293 ft. Fig. 15 shows some of the 40-in. conduit, together with a 30-in. blow-off, and the Lower Otay tunnel outlet.

METHODS ADOPTED IN ESTIMATING VALUES OF IMPROVEMENTS ON THE UNION PACIFIC RY.*

By J. B. Berry,† M. Am. Soc. C. E.

When the present owners of the Union Pacific Ry. took possession of the property Jan. 1, 1898, it was decided that extensive improvements should be made in order to put the road in condition for more economical operation. After a thorough examination of the conditions a general policy was agreed upon which has since been carried out, and for which the management has made liberal appropriations. The proposed improvements included increase in size of locomotives and capacity of cars, reduction of ruling gradients and elimination of as much distance, curvature, and rise and fall as was practicable. These improvements were to extend over all the main lines, but owing to the peculiar conditions existing on the Wyoming Division, Cheyenne to Ogden, a distance of 516 miles, the most radical changes were to be made there.

A careful study was made of the maps and profiles of the constructed line and the records of earlier surveys and explorations in the territory under consideration, and engineers were placed in the field to re-run some of the old lines and make additional surveys. It was decided that by doing some very heavy work, a ruling gradient of 0.82%, or 43.3 ft. per mile, could be established on the Wyoming Division, with the exception of the two places hereafter mentioned. The reduction of ruling gradients was considered the most important object to be attained in the relocation of the line, saving in distance next, reduction of total degrees of curvature third, and saving in rise and fall fourth. In addition to the more important work of reducing maximum grades, lowering main summits and avoiding the wide detours made by the old line, much attention was devoted to minor changes which would take out curvature or other features unfavorable to a high speed line.

It was found that at two places on the division it would be impossible to reduce the gradient to the adopted maximum and that helper grades would have to be retained, but that these could be materially improved. These places are: Cheyenne to Buford, 27 miles west-bound; and Ogden to Wahsatch, 65 miles east-bound, the latter stretch lying mostly in Weber and Echo Canyons and having grades varying from 53 to 96 ft. per mile. On this section the grades and alinement were, however, susceptible of considerable improvement. Between Buford and Wahsatch, a distance of 424 miles, it was found practicable to make the revisions necessary to obtain the proposed ruling gradient of 43.3 ft. per mile in each direction.

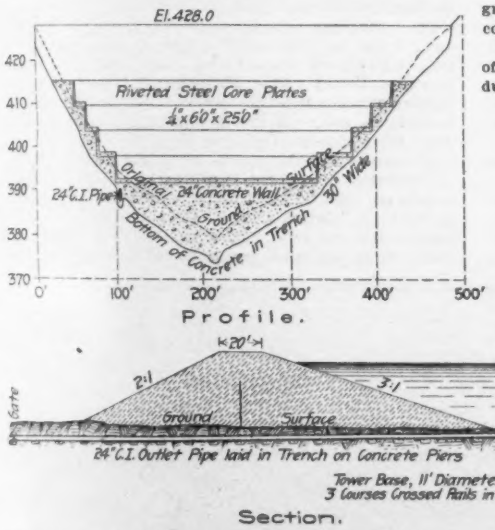


FIG. 12. CHOLLAS HEIGHTS EARTH DAM, WITH STEEL CORE PLATE AND CONCRETE WALL AT BASE.

In the Chief Engineer's office estimates were made of the various locations, and statements prepared showing comparisons of physical characteristics, and of the estimated annual saving in operation of the proposed lines as compared with the existing line. These comparative estimates were made in accordance with the method given by Mr. A. M. Wellington, using his classification of expenses and percentages affected by changes in gradients, distance, etc., but applied to the actual cost of operation on the Union Pacific Ry. for a period of years. The summary in Table A will give an approximate idea of what has been actually accomplished up to the termination of the fiscal year ending June 30, 1902, on the first four engine districts of the division. The operating statistics in Table A are deduced from reports made by the Auditor. "Before Change" shows the average for the two years ending June 30, 1900, and "After Change" for the year ending June 30, 1902. The reductions in gradient, distance, etc., are for the more important changes in the line; minor changes in line made in connection with revision of grade

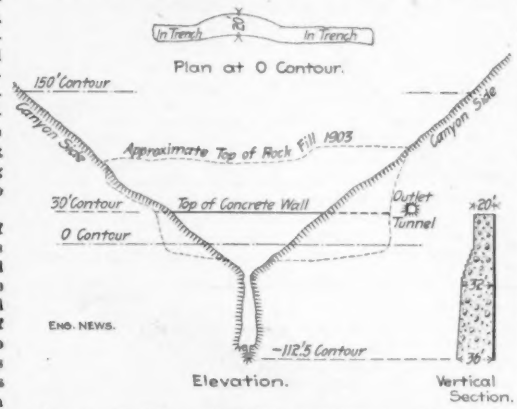


Fig. 9. Profile and Details of Moreno Rock Fill Dam, with Concrete Wall at Base.

work would increase these savings somewhat. On the district west of Evanston much improvement work has been done, especially in the canyon between Wahsatch and Ogden. Here a great deal of bad and dangerous curvature has been eliminated and revision of grade work prosecuted with a view to ultimately having a more uniform grade and better line.

It will be noted that on each district, except Cheyenne to Laramie, there has been a saving in distance and curvature as well as a reduction of gradient. On this district, which crosses the Rocky Mountains, with an increase in distance of only 0.37 miles and 86° additional curvature, the summit was lowered 236 ft., the east-bound grade reduced to the adopted maximum, the west-bound helper grade shortened about 6 miles, and reduced from 88 to 82 ft. per mile. The increase in the number of trains is due to increase in volume of traffic. The average weight of train behind engine and tender has been greatly increased, owing partly to reduction of grade and partly to the introduction of more powerful locomotives and larger cars.

It may appear to those unfamiliar with the character of the country that the great saving in distance and reduction of grade would stand as a criticism of the work of the pioneer engineers who made the original location of the railroad. Such is not the case. The changes made have been expensive and could be warranted only by the volume of traffic handled at the present day. Too much credit cannot be given Gen. G. M. Dodge and his assistants. They studied their task thoroughly and performed it well. Limited by law to a maximum gradient of 116 ft. to the mile, not compensated for curvature, they held it down to about 90 ft. per mile. Taking into consideration the existing conditions 35 years ago: lack of maps of the country, hostility of the Indians, which made United States troops necessary for protection of surveying parties, difficult transportation, excessive cost of labor, uncertainty as to probable volume of traffic, limited amount of money and necessity to get road built soon as possible, it can be said, with all our present knowledge of the topography of the country, that the line was located with very great skill.

ECONOMIC BASIS OF REVISION WORK.

In order to intelligently locate a line for a railway, it is essential that a study be made to determine what effect the location and construction cost of different routes would have on the operating expenses and fixed charges of the road. Any expenditure in construction which reduces operating expenses by an amount greater than the interest charges on such expenditure will be an economy. The volume of traffic being equal, the most economical location is that which will require the least expenditure to cover the combined cost of interest and operating expenses. The details of location affecting operating expenses are Gradients, Distance, Curvature, and Rise and Fall. As the effect of these details on operating expenses varies most directly with the number of trains operated, the "train mile" is used as the general operating unit.

In order to determine the relative merits of different locations, values must be ascertained for each detail affecting operating expenses. "The Economic Theory of Railway Location," by the late A. M. Wellington, treats the entire subject fully. In this work Mr. Wellington gave to engineers a logical method of obtaining the values for distance, curvature, rise and fall and gradients, but the modern classification of operating expenses as adopted by the Interstate Commerce Commission gives these expenses in greater detail than could be obtained during the life of Mr. Wellington. This detail is of material assistance in following out Mr. Wellington's general method, as it lessens the chance for error in judgment as to the proportion of each item of expense which will be affected by changes in the details of location. Prof. W. L. Webb, in his recent work on "Railroad Construction," has developed values for the various details, following the general method given by Mr. Wellington, but using the classification and figures given in the Reports of the Interstate Commerce Commission for the entire railway system of the United States. A study of these reports shows that the average cost per train mile in the more populous states is less than in the states west of the Missouri River.

In order to obtain a value of these details of location for the use of engineers in the Western states, the general methods of both Mr. Wellington and Prof. Webb are applied in this paper to the operating expenses of the Union Pacific Ry.

Table I. is deduced from statements of operating expenses for the four years ending June 30, 1902, and shows the percentage that each item of the table bears to the whole. The average cost per train mile is also shown, and this cost is divided between the items of the table according to the percentages shown.

Before proceeding to consider the value of gradients, distance, etc., it is necessary to obtain some basis for arriving at the proportional percentages of the more important items that are affected by changes in location. In many of the smaller items judgment alone has to be used, and in most of such cases a wide variation in judgment will produce but a slight change in the final figures.

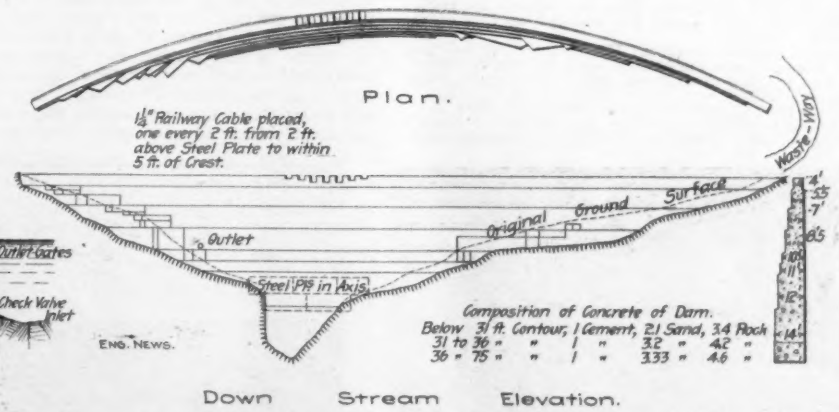

Plan.
1½" Railway Cable placed, one every 2 ft. from 2 ft. above Steel Plate to within 5 ft. of Crest.
Waste Weir
Outlet
Original Ground Surface
Steel Pls in Axis
ENG. NEWS.
Composition of Concrete of Dam.
Below 31 ft. Contour, 1 Cement, 2.1 Sand, 3.4 Rock
31 to 36 " " 1 " 3.2 " 4.2 "
36 " 75 " " 1 " 3.33 " 4.6 "
Down Stream Elevation.

FIG. 10. PLAN, ELEVATION AND DETAIL OF UPPER OTAY CONCRETE DAM, WITH STEEL PLATES AND CABLES, AS INDICATED.

In the larger items of Maintenance of Way, Maintenance of Equipment and Conducting Transportation, the reports of the various departments for the four years covered by Table I. have been studied and the conditions as they exist on the Union Pacific have been considered. The reasons for adopting these percentages are given in detail in Wellington's "Economic Theory of Railway Location." Tables Nos. 2, 3 and 4, together with the following notes, give some additional reasons, and also explain those points wherein percentages different from Wellington's have been used.

MAINTENANCE OF WAY.—Total side track mileage is about 34% of mileage of main track. One-half of side track mileage is in large yards and terminals, the balance being side tracks at intermediate stations. There is

*Abstract of a paper presented at the annual meeting of the American Railway Engineering and Maintenance of Way Association.

†Chief Engineer, Union Pacific Ry., Omaha, Neb. Mr. Berry acknowledges the assistance given him in the preparation of the matter by Messrs. Shurtleff and Cone, of the Engineering Department, Union Pacific Ry., and also by Mr. W. P. Watson, who was at one time an employee of that department.

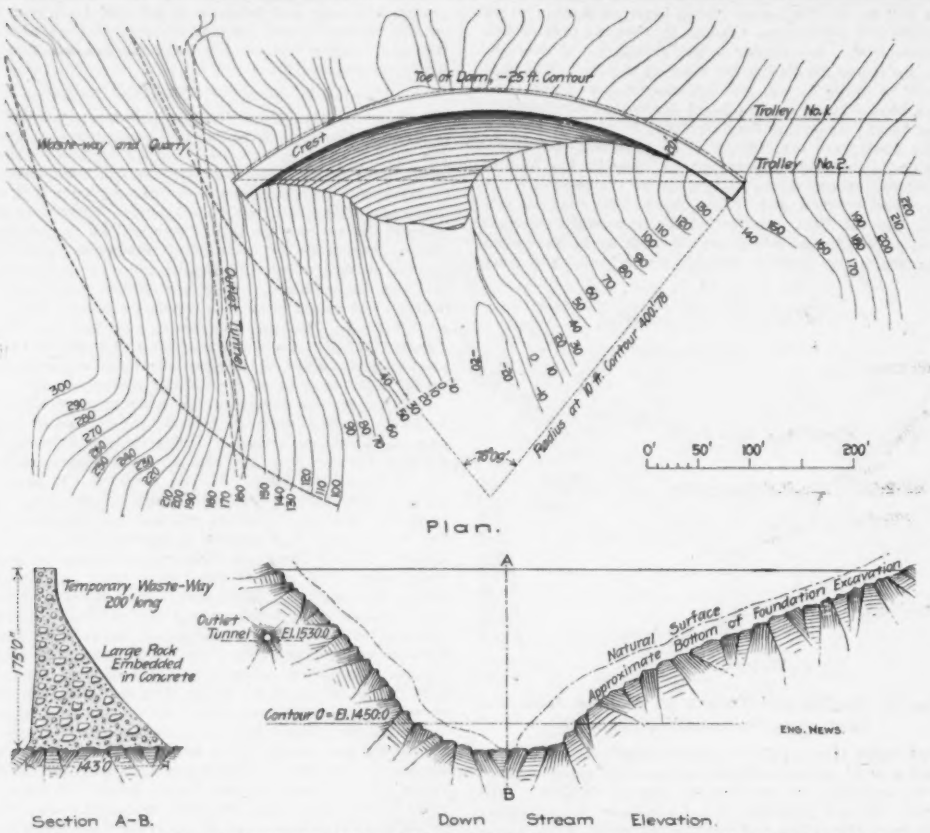


FIG. 13. PLAN, ELEVATION AND CROSS-SECTION OF BARRETT MASONRY DAM, AS PROPOSED.

probably about one-third as much labor spent on repairs of side tracks as on the same length of main track. The same is assumed to be true of material; hence in these calculations it will be assumed that labor and material in repairs of roadbed and track are distributed as follows:

Main track	90%
Large yards and terminals	5%
Smaller stations	5%
Total	100%

MAINTENANCE OF EQUIPMENT.—From the annual locomotive performance sheets and statistics of train service it is found that total train mileage is but 75% of total locomotive mileage. Table 2 is similar to a table given by Wellington, the total cost of locomotive repairs being prorated between the different classes of service according to mileage. The distribution with reference to contributing causes is changed somewhat to fit the conditions on the Union Pacific, curvature on the Union Pacific averaging 1° per mile, whereas Wellington assumed 30° per mile.

CONDUCTING TRANSPORTATION.—As only 75% of engine mileage enters into total train mileage, the wages of engine and roundhouse men due directly to hauling trains with single engine are assumed as 75% of the whole.

In train service only about 75% of the crews are paid on a mileage basis, the balance being on monthly wages, and any increase of distance, unless it be great, would affect only 75% of this item.

Fuel, water, oil and waste are covered by Table 4.

GENERAL EXPLANATION.—It must be thoroughly understood that the total train mileage includes the mileage of all passenger, freight, work and special trains, whether revenue or non-revenue. In the calculations as to the effect of the various details of location on operating expenses a single train is considered with a single locomotive. Therefore, none of the expense connected with helper, switch or light engine enters into the calculation, and only that proportion of the remainder of each item of operating expenses which is affected by gradient, distance, curvature, etc., is considered.

Any increase in repairs and renewals of shop machinery and tools caused by increase in gradients, distance or curvature is considered as proportional to the increase in repairs and renewals of locomotives and cars.

GRADIENTS.

The most important engineering problem affecting the operating expenses of a road is the question of the ruling gradient to be adopted. On short changes of line this question does not enter into consideration, as the maximum grade is always held within the limits allowed by the ruling grade of the engine district. On new lines, and on changes of line of some magnitude, it is an extremely important question. The ruling grade of an engine district governs the number of trains necessary to handle the traffic of that district, and should never be exceeded except where the character of the country is such as to make "helper grades" advisable. Any change that may be made in a line to reduce the ruling gradient will reduce the number of trains required to handle a given traffic. To get at the value of changes in ruling gradient the additional cost of running one more train per day to handle a given traffic will be considered.

As many items of expense will not be affected, the cost per train mile for the additional train will not be as large as the average cost per train mile for the entire traffic. Table 5 considers the percentage of the items of operating expenses which are affected by such an additional train as applied to the operating expenses per train mile on the Union Pacific Ry.

The saving per annum due to a reduction of gradient so that one less daily train in each direction can handle a given traffic will be as follows: $0.51 × twice the length of engine district × 365. Multiplying this product by the number of round-trip daily trains saved, and dividing by the interest rate, will give the justifiable expenditure to make the proposed reduction in gradient.

In order to find the number of freight trains saved by any reduction of gradient, it will first be necessary to ascertain the total trainload that can be hauled on different gradients by a given engine. Freight trains are of two classes, fast and slow. The slow freights are given the maximum tonnage that can be hauled on the ruling gra-

TABLE A.—Comparative Summary of Physical and Operating Characteristics, Union Pacific Ry.; Cheyenne to Evanston, Wyo., Before and After Revision.

	Cheyenne to Laramie.	Laramie to Rawlins.	Rawlins to Green River.	Green River to Evanston.	Total.
Length of district, miles:					
Before change	56.53	136.44	135.63	110.29	438.89
After change	56.90	116.99	134.16	100.08	408.13
Miles of new line built in making change	29.63	59.12	43.84	34.73	167.32
Maximum gradient, compensated, ft. per mile:					
Eastbound, before change	97.7	58.0	70.2	67.0	.....
Eastbound, after change	43.3	43.3	43.3	43.3	.....
Westbound, before change	88.0	75.3	67.6	68.6	.....
Westbound, after change	82.0	43.3	43.3	43.3	.....
Increase in total curvature, degrees	86	.....	.....	.....	.....
Decrease in total curvature, degrees	....	4,668	739	1,847	7,168
Decrease in rise and fall, ft.	162	128	77	265	632
Ave. number of daily trains each way:					
Before change, freight	6.66	6.57	6.17	4.50	.....
Before change, passenger	3.00	3.00	3.00	3.00	.....
After change, freight	7.52	7.12	6.19	4.44	.....
After change, passenger	4.00	4.00	4.00	4.00	.....
Helper engine mileage in actual assistance of trains per 1,000 freight train miles:					
Before change	369	246	290	344	.....
After change	180	3*	2*	35*	.....
Passenger helper engine mileage per 1,000 pasenger train miles for entire division:					
Before change	163	....	.....	.....	.....	.....
After change	21	....	.....	.....	.....	.....

*Helper engine mileage does not include return of light engine. The small amount of helper mileage "after change" on districts from Laramie to Green River is not due to helper grades. On district Green River to Evanston, the Aspen Tunnel line was not thrown open to operation until October, 1901, when helper service was discontinued.

Fig. 14. View of Lower Otay and San Diego Wood Stave Pipe Line in Mersh Canyon, Under 293-ft. Head.

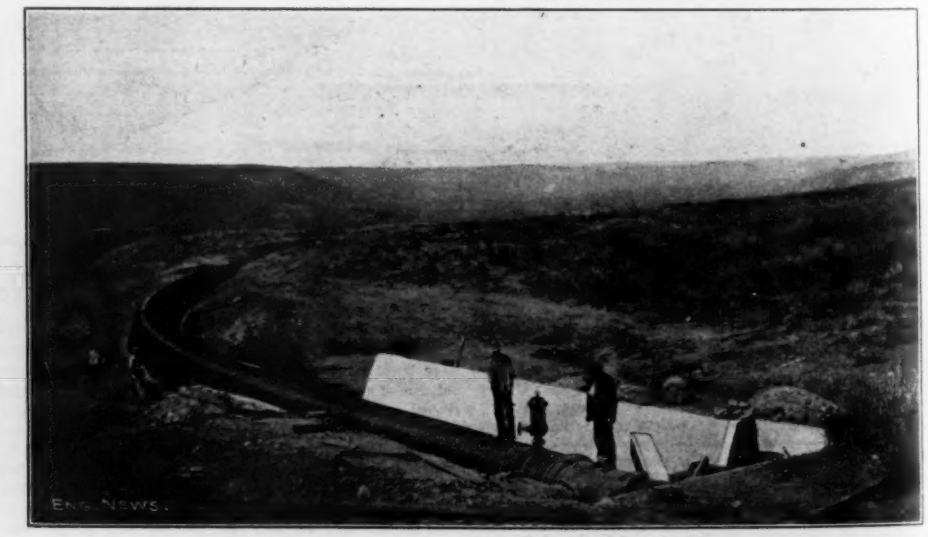


FIG. 15. VIEW OF LOWER OTAY TUNNEL OUTLET, 30-IN. BLOW-OFF, AND 42-IN. WOOD STAVE PIPE.

TABLE 1.—Statement Showing the Average Proportion that each Item of Operating Expenses bears to the whole on the Union Pacific R. R. for the Four Years Ending June 30, 1902.

Item No.	ITEM.	Per Cent. of Whole.
	Maintenance of Way and Structures:	
1	Ballast	0.28
2	Frogs and Switches	0.35
3	Protection of River Banks	0.03
4	Repairs of Roadbed and Track	8.33
5	Repairs of Snow Fences and Sheds	0.10
6	Spikes and Rail Fastenings	0.86
7	Superintendence	0.55
8	Renewals of Rails	2.28
9	Renewals of Ties	3.01
10	Repairs and Renewals, Bridges and Culverts	1.81
11	" " " Road Crossings, Signs, Cattle Guards, etc.	0.32
12	" " " Buildings and Fixtures	1.99
13	" " " Telegraph	0.15
14	Stationery and Printing	0.01
		20.07
	Maintenance of Equipment:	
15	Superintendence	0.63
16	Repairs and Renewals, Locomotives	10.19
17	" " " Passenger and Sleeping Cars	2.07
18	" " " Freight Cars	5.32
19	" " " Work Cars	0.51
20	" " " Shop Machinery and Tools	1.03
21	Stationery, Printing and Other Expenses	0.80
		20.55
	Conducting Transportation	
22	Superintendence	1.50
23	Engine and Round-house Men	10.10
24	Fuel for Locomotives	10.80
25	Water, Oil, Waste and Other Supplies for Locomotives	1.36
26	Train Service	5.55
27	Train Supplies and Expenses	1.91
28	Switchmen, Flagmen, Watchmen and Switching Charges	2.36
29	Telegraph Expenses	2.44
30	Station Service and Supplies	5.62
31	Car Mileage	0.61
32	Hire of Equipment	0.04
33	Loss and Damage to Freight, Property, Stock; Injury to Persons and Clearing Wrecks	1.88
34	Advertising, Agencies, Commissions, Rents for Buildings, Yards, etc.	4.66
35	Stationery and Printing	0.53
		49.36
36	Taxes Paid	5.64
37	General Expenses	4.38
	Grand Total	100.00
	Average Cost per Train Mile for the Four Years	$1.17

dient at a maintained speed of 10 or 12 miles per hour. Fast freights are given the train that can be hauled at a much higher velocity. Both classes would be affected by any change in gradient. Six pounds per ton of train is taken as a fair average for velocity and frictional resistance, equivalent to a speed of about 16 miles per hour. To get at the number of trains necessary to handle a given traffic it is necessary to find what weight of train, exclusive of engine and caboose, can be handled by the engines used on the district. This is found as follows:

$$\text{Weight in tons} = \frac{\text{Pounds Tractive Power}}{\text{Total pounds resistance per ton}} -$$

minus the weight of engine, tender and caboose in tons.

Table 6 gives this weight in tons for one of the modern Union Pacific locomotives.

No advantage except a reduction in time would be gained by reducing grade below 0.4%, as starting resistance of train on level would limit the weight of train. For other locomotives of modern type the weight of train would vary, depending on the tractive power, but the percentage of reduction in weight for increased grade would vary only slightly from the above. Table 7 is deduced from Table 6. The first column gives the gradient that it is proposed to reduce. The following columns give the percentage of trains necessary to handle the same traffic if grade is reduced to that given at the head of each column. Values for intermediate grades can be obtained by interpolation.

EXAMPLE.—An engine district 100 miles long has a ruling gradient of 1% in each direction. The freight traffic requires 10 daily trains each way. What expenditure would be justifiable to reduce the ruling gradient to 0.8%, with interest rate at 5% per annum? From Table 7 it is found that it would require only 83% of the number of trains to handle the traffic on an 0.8% grade that would be required on a 1% grade. This is a saving of 17%, or 1.7 trains each way per day. By the rule deduced from Table 5 the annual saving would be $0.51 \times 200 \times 365 \times 1.7 = \$63,291$. This sum capitalized at 5% is equal to $1,265,820, the expenditure justifiable to reduce the gradient.

In the above example the traffic is assumed as evenly balanced both ways. The same value would be obtained if the district considered were continually rising from one terminal to the other with the same ruling gradient, as a reduction of the gradient would reduce the number of engines and cabooses returning over the district either light or only partially loaded. From the foregoing it will be seen that whatever effort is put forth to reduce gradient should be expended in a manner to balance traffic as nearly as possible.

Ordinary changes in ruling gradients do not affect passenger trains materially except as to fluctuations in speed. The number of passenger trains depends but very little on ruling gradient and should be left out of the question in calculation of values of grade reduction, except where the grade can be reduced to such an extent as to entirely abolish the use of helper engine on passenger trains. In this case the saving can only be figured on the basis of reduction of cost of helper engines.

HELPER GRADES.

In some instances there exist topographical features that make necessary a gradient considerably in excess of the ruling gradient on the balance of the district. The reduction of this heavy gradient to the ruling gradient of the district might be so expensive as to be impracticable. Such grades are operated by a helper engine. This creates additional cost, and occasionally the cost is such that maintaining the helper grade is a greater annual expense than the interest on the cost of reducing the same to the ruling gradient, the helper engine having to pass twice over the grade for each train assisted. Each case must be considered by itself and the most economical method of operation should be adopted, the grades being adjusted to such method.

The greatest efficiency in helper engines is secured when the helper is kept constantly at work. To secure this efficiency the helper grade should be as nearly continuous and uniform as possible, rather than with stretches of lighter grade between grades where helper is necessary. The rate of helper grade should be such as to require the full power of the helper engine in addition to that of the regular engine to handle the maximum train that can be hauled by one engine over the balance of the district. This reduces the length of the necessary helper grade and consequently the helper engine mileage.

For two engines of the same class the combined theoretical tractive power would be double what one engine would exert, but in practice it is not safe to assume this. A conservative estimate would be that only 90% of the tractive power can be available in the helper engine. This 90% can not be wholly applied to lifting the train load, as part of it is required for overcoming resistance due to the weight of the locomotive. The amount used this way varies slightly with the type of engine and size of tender, but the following is a fairly accurate statement showing ruling gradient for one engine and equivalent helper gradient for same train and same class helper engine, counting 90% of tractive power of helper engine and velocity resistance of 5 lbs. per ton of train, equivalent to 12 miles per hour maintained speed for maximum train.

	Per cent.					
Ruling gradient, one engine	0.50	0.60	0.70	0.80	0.90	1.00
Equivalent gradient, one helper	1.09	1.25	1.41	1.58	1.73	1.89

On some roads of very light traffic it may not be economical to maintain helper engines at points where it has been considered necessary to establish helper grades with a view to future growth. In such cases the engine will "double" the grade, taking part of the load at each trip, but where a helper engine can be kept fairly busy it would be best to maintain the helper service. Usually a helper engine will make a daily mileage equal to the average freight engine mileage for the district, or from 100 to 125 miles per day.

The cost of helper engine service depends partly on the miles run, but some items are wholly independent of mileage. The maintenance of way items will be affected the same as for an additional engine to care for a given traffic. Wages of engine and roundhouse men for helper service are independent of distance; fuel and locomotive supplies will be at a higher rate except where engine is kept busy; locomotive repairs will mainly depend on mileage. There is a wide chance for variation in cost of helper engine mileage, and on operated lines where such service is maintained the actual cost of maintenance of equipment and conducting transportation should be obtained for use in calculations and added to the estimated cost of maintenance of way. The estimate given in Table 8 is a conservative one for a fairly busy helper engine.

Multiplying these figures by the total helper engine mileage or by the total train miles of assisted train will give cost per annum for helper service. Dividing this cost by the interest rate will give the justifiable expenditure to reduce the helper grade to the ruling grade of the balance of the district. Where it is not advisable or economical to reduce a helper grade to the proposed ruling gradient for single engine, the line and grades on either side should be adjusted so that when the business

TABLE 2.—Statement Showing Distribution of Cost of Locomotive Repairs on Union Pacific R. R.

Class of Service.	Per Cent. Repairs Charged Each Class.	Distribution of Contributing Causes in Per Cent.					
		Time and Exposure.	Stopping and Starting.	Getting up Steam and Terminal Work.	Average Curvature.	Average Grades.	Distance.
Passenger	31.50	2.20	4.73	5.35	0.95	4.41	13.86
Freight and Work	43.26	3.03	6.49	7.35	1.30	6.05	19.03
Helpers	5.46	0.38	0.82	0.82	0.16	2.18	1.10
Light Engines*	6.38	0.45	0.64	1.68	0.19	0.32	3.70
Switching	13.41	0.94	....	12.47	....	....	....
	100.00	7.00	12.68	27.07	2.60	12.96	37.69

*Light engine mileage includes return of helper engines. Only the first two classes enter into train mileage.

TABLE 3.—Statement Showing Distribution of Cost of Car Repairs on Union Pacific R. R.

Class of Service.	Total Cost per Cent.	Distribution of Contributing Causes in Per Cent.					
		Time and Exposure	Stopping and Starting	Switching	Curvature.	Grades.	Distance.
Passenger	100	11	29	11	2	20	36
Freight and Work	100	6	20	16	2	20	36

TABLE 4.—Statement Showing Average Percentage Per Year of Various Classes of Engine Mileage and Percentages of Fuel, Water, Oil, Waste and Engine Supplies Used by Each Class, with Distribution of Same, for the Four Years Ending June 30, 1902.

Class of Service.	Per Cent. Mileage Each Class.	Fuel Used Each Class Service.							Water, Oil, Waste and Locomotive Supplies.						
		Per Cent. Used.	Distribution, Per Cent of Whole.						Per Cent Used.	Distribution, Per Cent of Whole.					
			Starting and Banking Fires.	Waste, Standing	Stopping and Starting.	Average Curvature.	Average Grade.	Distance.		Waste, All Sources.	Stopping and Starting.	Average Curvature.	Average Grade.	Distance.	
Passenger	31.50	25	1.25	0.75	2.50	.37	5.00	15.13	28	1.40	3.08	.42	5.60	17.50	
Freight and Mixed	40.08	46	2.30	1.38	4.60	.69	9.20	27.83	43	2.15	4.73	.64	8.60	26.88	
Work Trains	3.17	4	.20	.12	.40	.06	.80	2.42	4	.20	.44	.06	.80	2.50	
Helpers	5.46	10	.50	.30	1.00	.15	2.00	6.05	8	.40	.88	.12	1.60	5.00	
Light Engines	6.38	3	.15	.09	.30	.05	.60	1.81	5	.25	.55	.08	1.00	3.12	
Switching	13.41	12	.60	.36	1.20	.18	2.40	7.26	12	.60	1.32	.18	2.40	7.50	
Totals	100.00	100	5.00	3.00	10.00	1.50	20.00	60.50	100	5.00	11.00	1.50	20.00	62.50	

The first three classes of service are the classes that total train mileage is calculated from. Total train mileage averaged 74.75% of total engine mileage.

Per cent. fuel, water, oil, etc., used is based on the statements of locomotive performance for the four years. Helper mileage is mileage of actual helping, the return of helpers being included in light engines.

The distribution of the use of fuel, etc., is according to the theory of Wellington, the percentage used being changed somewhat to suit the conditions on Union Pacific.

TABLE 5.—Cost Per Train Mile for an Additional Train to Handle a Given Traffic.

Item No.	ITEM.	Normal Average Cost Per Cent	Proportion Affected. %	Per Cent. Cost per Train Mile for Additional Train.
1	Ballast	0.28	0	....
2	Frogs and Switches	0.35	50	0.18
3	Protection of River Banks	0.03	0	....
4	Repairs of Roadbed and Track	8.33	50	4.16
5	Repairs of Snow Fences, etc.	0.10	0	....
6	Spikes and Rail Fastenings	0.86	50	0.43
7	Superintendence (M. of Way)	0.55	0	....
8	Renewals of Rails	2.28	50	1.14
9	Renewals of Ties	3.01	50	1.50
10	Rep and Renewals, Bridges and Culverts	1.81	5	0.09
11	" " " Road Crossings, Cattle Guards, etc.	0.32	0	....
12	" " " Buildings, etc.	1.99	0	....
13	" " " Telegraph	0.15	0	....
14	Stationery and Printing (M. of Way)	0.01	0	....
15	Superintendence (M. of Equipment)	0.63	0	....
16	Repairs and Renewals, Locomotives	10.19	70	7.13
17	" " " Passenger Cars	2.07	0	....
18	" " " Freight Cars	5.32	—5	—0.27
19	" " " Work Cars	0.51	0	....
20	" " " Machinery and Tools	1.03	35	0.36
21	Stationery, etc (M. of Equipment)	0.80	0	....
22	Superintendence (Transportation)	1.50	0	....
23	Engine and Round-house Men	10.10	75	7.58
24	Fuel for Locomotives	10.80	75	8.10
25	Water, Oil, Waste and Supplies (locomo.)	1.36	75	1.02
26	Train Service	5.55	100	5.55
27	Train Supplies and Expenses	1.91	90	1.72
28	Switchmen, Flagmen, etc	2.36	50	1.18
29	Telegraph Expenses	2.44	20	0.49
30	Station Service and Supplies	5.62	20	1.12
31	Car Mileage	0.61	0	....
32	Hire of Equipment	0.04	0	....
33	Loss and Damage, etc.	1.88	75	1.41
34	Advertising, Agencies, etc.	4.66	0	....
35	Stationery, etc. (Transportation)	0.53	75	0.40
36	Taxes	5.64	0	....
37	General Expenses	4.38	0	....
	Total Per Cent.	100.00		43.29
	Cost per train mile for additional train: 43.29% of $1.17			$0.50
	Add interest on cost of additional locomotive and caboose per train mile			.01
	Total cost per train mile for additional train			$0.51

For each engine going over a district one must be returned in order to keep power equalized. To reduce train mileage it would be necessary to reduce the grade, so that for every train less in one direction there would be one less train in the opposite direction; or, in other words, there must be two train miles saved for each track mile of engine district.

TABLE 6.—Total Weight of Train Between Engine Tender and Caboose for Various Gradients, for Locomotive and Tender Weighing 150.3 Tons in Working Order; Tractive Power, 35,268 lbs.; Weight of Caboose, 17 Tons; Velocity and Frictional Resistance, 6 lbs. per Ton.

Gradient. Per Cent.	Weight of Train. Tons.	Gradient. Per Cent.	Weight of Train. Tons.	Gradient. Per Cent.	Weight of Train. Tons.
0.4	2352	1.0	1190	1.6	761
0.5	2037	1.1	1092	1.7	714
0.6	1792	1.2	1008	1.8	672
0.7	1596	1.3	935	1.9	634
0.8	1436	1.4	870	2.0	599
0.9	1302	1.5	812		

justifies the change it can be without rebuilding any more than the portion where the helper grade is located.

DISTANCE.

The various items of operating expenses in Table 1 are not affected equally by changes in length of line. Some are not affected in the least, while others will vary directly with increase or decrease in distance. Where the change in distance is so small as not to affect the number of engine districts or large yards, only the labor and material used in main track and intermediate yards will be affected.

Tables 2, 3 and 4 show the per cent. of charges to locomotive and car repairs and locomotive fuel and supplies that can be reasonably assumed as due to distance. Switch engine mileage will not be affected and helper engine service has been considered, so the only classes of service to be considered are passenger, freight and work trains.

On very short changes in distance, the wages of enginemen and trainmen will not be affected, neither will some of the items of maintenance of way. On longer changes these items will be affected, and on changes so great as to affect the number of stations and sidings still further items will be affected. Therefore, changes in distance will be considered under three classes, viz.:

Class "A"—Distances so short as not to affect train wages.

Class "B"—Distances affecting train wages, but not so great as to affect the number of stations or sidings required.

Class "C"—Distances so great as to affect the number of stations and sidings required.

Table 9 shows the estimated cost per train mile for increase in distance for each class, from which costs per daily train per annum are deduced. Multiplying the cost per daily train one way, per annum, by the sum of the number of trains in each direction, and dividing this product by the interest rate, will give the justifiable expenditure to eliminate one foot of distance for Class "A," or one mile of distance for Classes "B" and "C."

CURVATURE.

No logical value can be placed on the elimination of a single curve where the total degrees of curvature are not reduced. Where a curve is located in a particularly dangerous place, requiring a watchman or other additional expense for protection, its elimination would have a value, but each case would have to be considered by itself. In comparing the relative values of two lines, unless the curve is particularly dangerous, it is best to consider only the value of reducing the total degrees of curvature.

To get at the value of curvature it will be treated as an increase, and the increase to operating expenses noted.

Average train resistance can be safely assumed as about 10 lbs. per ton. This is equivalent to a velocity of about 28 miles per hour on a level tangent. Curvature on the Union Pacific is compensated at 0.04% per degree of curvature (equivalent to 0.8 lb. per ton of train). The resistance on a 12° 30′ curve would be 10 lbs. per ton, hence on a 12° 30′ curve with a level track resistance would be twice the average. To find the value for elimination of a degree of curvature, the addition to operating expenses due to one mile of 12° 30′ curve with a total angle of 660° is considered in Table 10.

TABLE 8.—Estimated Cost of a Helper Engine Mile in Per Cent. of Cost of a Normal Train Mile.

Item. No.	ITEM.	Normal Average Cost. Per Cent.	Proportion Affected. %	Cost per Helper Engine Mile. Per Cent.
2	Frogs and Switches	0.35	50	0.18
4	Repairs, Roadbed and Track	8.33	50	4.16
6	Spikes and Rail Fastenings	0.86	50	0.43
8- 9	Renewals of Rails and Ties	5.29	50	2.64
10	Repairs and Renewals, Bridges and Culverts	1.81	5	0.09
16	Repairs and Renewals, Locomotives	10.19	75	7.64
23	Engine and Round-house Men	10.10	75	7.58
24-25	Fuel, Water, etc., Locomotives	12.16	75	9.12
28	Switchmen, Flagmen and Watchmen	2.38	50	1.19
29	Telegraph Expenses	2.44	20	0.49
	Total			33.52

Cost per helper engine mile, 33.52% of $1.17 ..... $0.392
Add interest on cost of engine, approximate cost per mile 0.010
Total $0.402
Cost per helper engine-mile per annum, $0.402 × 365 = $146.73.
As helper must run light on return trip, the cost of helper service per train mile assisted train per annum would be $146.73 × 2 = $293.46.

TABLE 7.—Table Showing Per Cent. of Train Necessary to Handle a Given Traffic with Single Engine, if Gradients Are Changed from Those in First Column to Any Other Given Gradient.

Gradient to be Reduced. Per Cent.	Proposed Gradient, Per Cent., with Per Cent. of Trains to Handle same Traffic as on Original Gradient.																
	+0.4	+0.5	+0.6	+0.7	+0.8	+0.9	+1.0	+1.1	+1.2	+1.3	+1.4	+1.5	+1.6	+1.7	+1.8	+1.9	+2.0
2.0	26	30	34	38	42	46	51	55	60	65	69	74	79	84	89	95	100
1.9	27	31	36	40	44	49	54	58	63	68	73	78	84	89	95	100	
1.8	29	33	38	42	47	52	57	62	67	72	78	83	89	94	100		
1.7	31	35	40	45	50	55	60	66	71	77	82	88	94	100			
1.6	33	37	43	48	53	59	64	70	76	82	88	94	100				
1.5	35	40	46	51	57	63	68	75	81	87	93	100					
1.4	37	43	49	55	61	67	73	80	87	93	100						
1.3	40	46	53	59	66	72	79	86	93	100							
1.2	43	50	57	64	71	78	85	92	100								
1.1	47	54	61	69	76	84	92	100									
1.0	51	59	67	75	83	91	100										
0	55	64	73	82	91	100											
0.8	61	71	80	90	100												
0.7	68	79	89	100													
0.6	76	88	100														
0.5	87	100															
0.4	100																

Tables 2, 3 and 4 show the average per cent. of charges per train mile against passenger, freight and work trains due to average curvature, but for a train mile having 660° of curvature there is 40 times the average amount.

Multiplying the cost per daily train one way per degree, per annum, by the sum of the number of trains in each direction, and dividing this product by the interest rate, will give the justifiable expenditure to eliminate one degree of curvature.

RISE AND FALL.

In considering the value of Rise and Fall it will be divided into three classes, as given by Wellington:

Class "A" includes all cases where grades are so light or so short as not to require the use of brakes or variation in the working of the engine.

Class "B" includes all cases where grades are such as to require shutting off steam in descending, but are not long enough to require application of brakes to prevent exceeding the maximum safe speed.

Class "C" includes all cases where grades are so heavy as to necessitate not only shutting off steam, but the application of brakes in descending.

One foot up and one foot down is called one foot of rise and fall. It will be seen in considering velocity and virtual grades that the number of feet-rise and fall for any particular class will vary with the actual grade, the speed of approach and the controlling grade of line under consideration. To get at the true class a virtual profile should be worked up for each line. For estimating purposes the following limits for the divisions will be adopted:

Class "A:" All rise and fall up to 30 ft. This class of rise and fall adds so little to the operating expenses that it need not be considered in comparing value of lines.

Class "B:" All rise and fall of over 30 ft. on grades of less than 0.6%, since the maximum velocity that can be attained on a 0.6% grade by a train dropping of its own weight is about 32 miles per hour, for at this velocity the train resistance just equals the force of gravity. Owing to the fact that curves may be located near the bottom of grades, the maximum safe speed will be considered at about 30 miles per hour. On grades of 0.6% and over, the following figures show the approximate distances trains would run with steam shut off and with initial speed of 10 miles per hour before reaching 30 miles per hour speed, the distance run being given in stations of 100 ft.

	Per cent.						
Gradient ..	— 0.6	— 0.7	— 0.8	— 0.9	— 1.0	— 1.25	— 1.50
	Stations.						
Distance ...	170	100	73	57	48	33	26
	Feet.						
Total drop..	102	70	58	51	48	41	38

On above gradients all rise and fall of over 30 ft. and up to above total drop belong to Class "B."

Class "C:" All rise and fall on grades of 0.6% and over in excess of total drop given in above statement.

The average resistance of a train is about 10 lbs. per ton of train, equivalent to the resistance on a level tangent at a velocity of 28 miles per hour. The resistance due to grade alone on a 0.5% grade is 10 lbs. per ton. Therefore, the total resistance on a mile of 0.5% grade is double the resistance on one mile of level tangent. To get at the value of rise and fall it will be assumed that there are two miles of tangent, the first mile having an ascending grade of 0.5% and the second mile a descending grade of the same rate, the two miles containing 26.4 ft. of rise and fall. Table 11 shows the estimated additional cost per train mile due to this 26.4 ft. of rise and fall from which values are deduced for one foot of rise and fall of each class.

Additional cost per train mile due to the rise and fall:

Class "B" 3.38% of $1.17 equals $0.0395.
Class "C" 7.13% of $1.17 equals $0.0834.

If the rise and fall is on gradients equal to or in excess of the ruling gradient, add 3 cts. per train mile to above for wear and tear of rolling stock and track, making Class "B" 6.95 cts., and Class "C" 11.34 cts. per train mile. Additional cost per annum of one foot rise and fall, per daily train, one way:

On Minor Grades.

Class "B" $\frac{.0395 \times 365}{26.4} = \$0.55$

Class "C" $\frac{.0834 \times 365}{26.4} = \$1.15$

On Ruling Grades.

Class "B" $\frac{.0695 \times 365}{26.4} = \$0.96$

Class "C" $\frac{.1134 \times 365}{26.4} = \$1.57$

Multiplying the above costs per foot of rise and fall by the total number of trains in both directions, and dividing by the interest rate, will give the justifiable expenditure to eliminate one foot of rise and fall.

In using the values for elimination of rise and fall, the engineer must bear in mind that rise and fall for heavy freight trains may lie in Class "B" or "C," while for passenger trains it may lie in the less expensive class, owing to the higher velocity allowed passenger trains. This is best determined by platting the virtual grade line for each class of train.

TABLE 9.—Effect on Operating Expenses of Changes in Distance.

Class "A."—Distances so short as not to affect wages of engine or train men.

Class "B."—Distances affecting train wages, but not requiring additional side tracks.

Class "C."—Distances so great as to require additional side tracks and station.

Cost per additional train mile of each class:

Class "A," 32.10% of $1.17 = $0.3756.
Class "B," 45.94% of $1.17 = $0.5375.
Class "C," 59.05% of $1.17 = $0.6909.

The additional cost per annum per daily train one way would be:

Class "A," $\frac{0.3756 \times 365}{5280} = \$0.026$ for each additional foot of distance.

Class "B," $0.5375 × 365 = $196.19 for each additional mile of distance.

Class "C," $0.6909 × 365 = $252.18 for each additional mile of distance.

Item No.	ITEM	Normal Average Cost Per Cent.	Proportion of Whole Affected. % A	B	C	Added Proportional Cost for One Train Mile. Per Cent. A	B	C
1	Ballast	0.28	95	95	100	0.27	0.27	0.28
2	Frogs and Switches	0.35	0	0	50	.....	.....	0.17
3	Protection of River Banks	0.03	100	100	100	0.03	0.03	0.03
4	Repairs, Roadbed and Track	8.33	90	90	95	7.50	7.50	7.92
5	" Snow Fences, etc	0.10	100	100	100	0.10	0.10	0.10
6	Spikes and Rail Fastenings	0.86	90	90	95	0.77	0.77	0.82
7	Superintendence (M of Way)	0.55	0	0	0	.....	.....	.....
8	Renewals of Rails	2.38	90	90	95	2.05	2.05	2.17
9	" of Ties	3.01	90	90	95	2.71	2.71	2.86
10	Rep. and Renewals, Bridges and Culverts	1.81	0	100	100	.....	1.81	1.81
11	Rep. and Renewals, Road Crossings, Cattle Guards, etc	0.32	0	90	95	.....	0.29	0.30
12	Rep. and Renewals, Buildings, etc	1.99	0	0	30	.....	.....	0.60
13	" " Telegraph	0.15	60	60	75	0.09	0.09	0.11
14	Stationery and Printing (M. of Way)	0.01	90	90	95	0.01	0.01	0.01
15	Superintendence (M. of Equipment)	0.63	0	0	0	.....	.....	.....
16	Rep. and Renewals, Locomotives	10.19	33	33	44	3 36	3 36	4 48
17	" " " Passenger Cars	2.07	36	36	56	0.75	0.75	1.16
18	" " " Freight Cars	5.32	36	36	56	1 91	1 91	2.98
19	" " " Work Cars	0.51	36	36	56	0 18	0 18	0.28
20	" " " Machinery, etc	1.03	34	34	49	0.35	0.35	0.50
21	Stationery, etc (M. of Equipment)	0.80	34	34	49	0.27	0.27	0.39
22	Superintendence (Transportation)	1.50	0	0	0	.....	.....	.....
23	Engine and Round-house Men	10.10	0	75	75	.....	7 58	7 58
24	Fuel for Locomotives	10.80	45	45	50	4.86	4.86	5 04
25	Water, Oil, etc., for Locomotives	1.36	45	45	55	0.61	0.61	0.75
26	Train Service	5.55	0	75	75	.....	4 16	4 16
27	" Supplies and Expenses	1.91	50	50	50	0.95	0.95	0.95
28	Switchmen, Flagmen, etc	2.38	0	0	20	.....	.....	1.18
29	Telegraph Expenses	2.44	20	20	20	0.49	0.49	0.49
30	Station Service and Supplies	5.62	0	0	80	.....	.....	4.50
31	Car Mileage	0.61	100	100	100	0.61	0.61	0.61
32	Hire of Equipment	0.04	0	0	0	.....	.....	.....
33	Loss and Damage, etc	1.80	75	75	75	1.41	1.41	1.41
34	Advertising, Agencies, etc	4.56	0	0	0	.....	.....	.....
35	Stationery, etc. (Transportation)	0.38	0	0	0	.....	.....	.....
36	Taxes	5.84	50	50	50	2.92	2.92	2.92
37	General Expenses	4.38	0	0	0	.....	.....	.....
	Total, Per Cent	100.00				32 10	45.94	59.05

TABLE 10.—Effect on Operating Expenses of One Mile of 12° 30' Curve. (Total angle 660°.)

Item No.	ITEM.	Normal Average Cost, Per Cent.	Proportion Affected. $	Additional Cost due to Curvature. Per Cent.
1	Ballast	0.28	50	0.14
2	Frogs and Switches	0.35	0	....
3	Protection of River Banks	0.03	0	....
4	Repairs of Roadbed and Track	8.33	50	4.17
5	Repairs of Snow Fences, etc.	0.10	0	....
6	Spikes and Rail Fastenings	0.86	100	0.86
7	Superintendence (M. of Way)	0.55	0	....
8	Renewals of Rails	2.28	300	6.84
9	Renewals of Ties	3.01	50	1.50
10	Rep. and Renewals, Bridges and Culverts	1.81	0	....
11	" " " Road Crossings, Cattle Guards, etc	0.32	0	....
12	" " " Buildings, etc	1.99	0	....
13	" " " Telegraph	0.15	0	....
14	Stationery and Printing (M. of Way)	0.01	0	....
15	Superintendence (M. of Equipment)	0.63	0	....
16	Repairs and Renewals, Locomotives	10.19	90	9.17
17	" " " Passenger Cars	2.07	80	1.66
18	" " " Freight Cars	5.32	80	4.25
19	" " " Work Cars	0.51	80	0.41
20	" " " Machinery and Tools	1.03	85	0.88
21	Stationery, etc. (M. of Equipment)	0.80	0	....
22	Superintendence (Transportation)	1.50	0	....
23	Engine and Round-house Men	10.10	0	....
24	Fuel for Locomotives	10.80	45	4.86
25	Water, Oil, Waste and Supplies, Locomo.	1.36	45	0.61
26	Train Service	5.55	0	....
27	Train Supplies and Expenses	1.91	0	....
28	Switchmen, Flagmen, etc	2.36	0	....
29	Telegraph Expenses	2.44	0	....
30	Station Service and Supplies	5.62	0	....
31	Car Mileage	0.61	0	....
32	Hire of Equipment	0.04	0	....
33	Loss and Damage, etc	1.88	0	....
34	Advertising, Agencies, etc	4.66	0	....
35	Stationery, etc. (Transportation)	0.53	0	....
36	Taxes	5.64	0	....
37	General Expenses	4.38	0	....
	Total, Per Cent.	100.00		35.35

Where curvature is compensated for grade, the increase for fuel, water, etc., will be cut out, making the increased cost for the one mile of curvature 29.88%.
Additional cost for the train mile on 12° 30' curve:
35.35% of $1.17 = $0.4136 for uncompensated curvature.
29.88% of $1.17 = $0.3496 for compensated curvature.
Cost per degree, per daily train, per annum:

$$\frac{0.4136 \times 365}{660} = \$0.23 \text{ for uncompensated curves.}$$

$$\frac{0.3496 \times 365}{660} = \$0.19\frac{1}{8} \text{ for compensated curves.}$$

TRAIN RESISTANCE.

There are many formulas for train resistance, giving widely different results. In a number of experiments conducted by Wellington it was found that, at a given velocity, the resistance in pounds per ton of train varied with the type, load and number of cars in the train, or that, in two trains of the same gross weight but with a different number or type of cars, the resistances will be different at the same velocity.

Wellington's formula for resistance in pounds per ton for loaded trains is as follows:

$$R = 4 + .005\ V^2 + (.28 + .03\ N)\ \frac{V^2}{W}$$

R = Resistance in pounds per ton; V = Velocity in miles per hour; N = Number of cars to train; W = Weight of train in 2,000-lb. tons.

The first term represents the journal and rolling friction, the second term the resistance due to oscillation and concussion, and the third term atmospheric resistance.

Recent experiments by the Pennsylvania Railroad would indicate that this journal resistance is too high for modern cars having a gross weight of 30 tons or more. A modern coal car with 40 to 50 tons of coal will not have a journal friction of more than 2½ lbs. per ton, while the same car empty will have a journal friction of about 5 lbs. per ton. As trains are made up varying in amount of weight per car and number of cars, an empirical formula for resistance is given by Wellington which is generally used in the calculation of resistance in computing tonnage for a given tractive power. This formula is

$$R = 4 + \frac{V^2}{130}.$$

This formula gives a value for the resistance which is conservative for the average train at velocities from 5 to 35 miles per hour, although many recent experiments would indicate that the resistances at the higher velocities are not so great as the formula would indicate. For the purposes used herein the formula gives a "factor of safety," as any revision of grade in which this formula is used in constructing a virtual profile can be operated with greater ease by a train in case the resistances are less than those given by the formula.

When trains have been standing still for several minutes, the starting resistance is as high as 18 or 20 lbs. per ton of train, but this resistance rapidly decreases as the train gets under motion. In case the ruling gradient of a district is very light, the maximum train load may be limited by this starting resistance, but the entire mass of the train is not started at the same instant, owing to the spring of the couplings, so that the grade line at a station need not be adjusted to the full amount that theory would indicate in order to facilitate the starting of trains. Where practicable, it is advisable to make the gradient through the station grounds, and for a train length outside of the switches, at least 0.4% less than the ruling gradient.

In addition to the velocity and frictional resistances there is grade resistance. This, expressed in pounds per ton of train, is 20 times the rate per cent. of grade.

The total resistance to be overcome would then be represented by the formula:

$$R = 4 + \frac{V^2}{130} + 20 \text{ times rate per cent. of grade.}$$

TABLE 12.—Mean Effective Pressure in Cylinders in Per Cent. of Boiler Pressure for Various Piston Speeds in Feet Per Minute.

Piston Speed, Feet.	M. E. P. $	Piston Speed, Feet.	M. E. P. $	Piston Speed, Feet.	M. E. P. $	Piston Speed, Feet.	M. E. P. $
250	85.0	500	62.0	750	43.5	1000	31.6
300	80.2	550	58.0	800	40.7	1050	29.8
350	75.5	600	54.0	850	38.0	1100	28.3
400	70.8	650	50.0	900	35.7	1150	27.0
450	66.4	700	46.5	950	33.6	1200	26.0

Below 250 ft., the pressure is about the same, although there is probably a slight increase on starting.

TRACTIVE POWER OF LOCOMOTIVES.

$$\text{Formula: Tractive power} = \frac{C^2 \times P \times S}{D}$$

C = Diameter of cylinder in inches.
P = Mean effective pressure of steam in cylinder.
S = Stroke of piston in inches.
D = Diameter of drivers in inches.

Tractive power can never exceed adhesion, however, and maximum adhesion should never be considered as more than 25% of weight on the drivers. This will seldom be developed except in starting and by using sand. Where rail is dry adhesion can be safely estimated at 22½% of weight on drivers, but where frosty or wet it should not be estimated as greater than 20%. Well designed locomotives will develop a tractive power equal to this rate of adhesion at 10 miles per hour velocity. Bulletin No. 1, American Railway Engineering and Maintenance of Way Association, shows the results of a series of practical experiments and tests in connection with locomotive tractive power made by the Southern Pacific Company. In this work is shown the average mean effective pressure per square inch of cylinder in per cent. of boiler pressure for various piston speeds. Table 12 shows the drop in M. E. P. as piston speed increases, as shown on the curve adopted as a safe pressure for estimating tractive power in simple locomotives.

From the table it can be seen that tractive power decreases as speed increases. This decrease in tractive power for velocities expressed in miles per hour is not the same in all locomotives and diameters of drivers. Considering tractive power as 100% at 10 miles an hour velocity, the decrease in power as velocity increases will be the same for locomotives having the same ratio of diameter of drivers to stroke. Table 13 shows the reduction in tractive power in some of the modern Union Pacific locomotives.

Table 13 is calculated from Table 12, the piston speed for each velocity in miles per hour being first ascertained and the mean effective pressure in per cent. for each piston speed taken from the table. Then for the various train velocities the tractive power would vary directly with the per cent. of M. E. P.

MAXIMUM TRAIN LOAD.

Economy in operation of a railroad demands that locomotives be given the maximum load that can be hauled up the ruling gradient at a given rate of maintained speed. This rate of speed will vary with the character of the service, but should never be considered less than 10 miles per hour. The gross train load that can be hauled by a locomotive is ascertained by dividing the tractive power of the locomotive at the given rate of maintained speed by the total resistance in pounds per ton of train. This gives the total tons of train, including engine and tender. Subtracting the weight of engine and tender from the gross train load gives weight of train behind locomotive.

SUMMARY.

Before beginning work on a new location the chief engineer will indicate the character of the proposed line, probable volume of traffic expressed in tons and trains per day, and the size and tractive power of the locomotive to be used. For the field engineer the following approximate formulas are introduced and the values given for reduction in gradient, distance, curvature and rise and fall.

For general purposes the tractive power of a locomotive can be considered at 20% of the weight on drivers at a velocity of 10 or 12 miles per hour, although with fair weather conditions a well-designed locomotive should develop a tractive power of 22½% of the weight on drivers at 10 miles per hour.

Assuming 6 lbs. per ton velocity and frictional resistances as a fair average for slow and fast freights, with grade resistance 20 times the rate per cent. of grade:

TABLE 11.—Effect on Operating Expenses of One Mile Containing 26.4 ft. of Rise and Fall.

Item No.	ITEM.	Normal Average Cost, Per Cent.	Proportion of Whole Affected, $		Additional Cost for 26.4 Feet Rise and Fall, Per Cent.	
			Class B	Class C	Class B	Class C
1	Ballast	0.28	0	5	.....	0.01
2	Frogs and Switches	0.35	0	0	.....	.....
3	Protection of River Banks	0.03	0	0	.....	.....
4	Repairs of Roadbed and Track	8.33	0	5	.....	0.42
5	Repairs of Snow Fences, etc.	0.10	0	0	.....	.....
6	Spikes and Rail Fastenings	0.86	5	10	0.04	0.09
7	Superintendence (M. of Way)	0.55	0	0	.....	.....
8	Renewals of Rails	2.28	5	10	0.11	0.23
9	Renewals of Ties	3.01	0	5	.....	0.15
10	Rep and Renewals, Bridges and Culverts	1.81	0	0	.....	.....
11	" " " Road Crossings, Cattle Guards, etc	0.32	0	0	.....	.....
12	" " " Buildings, etc	1.99	0	0	.....	.....
13	" " " Telegraph	0.15	0	0	.....	.....
14	Stationery and Printing (M. of Way)	0.01	0	0	.....	.....
15	Superintendence (M. of Equipment)	0.63	0	0	.....	.....
16	Repairs and Renewals, Locomotives	10.19	1	4	0.10	0.41
17	" " " Passenger Cars	2.07	1	4	0.02	0.08
18	" " " Freight Cars	5.32	1	4	0.05	0.21
19	" " " Work Cars	0.51	1	4	0.01	0.02
20	" " " Machinery and Tools	1.03	1	4	0.01	0.04
21	Stationery, etc. (M. of Equipment)	0.80	0	0	.....	.....
22	Superintendence (Transportation)	1.50	0	0	.....	.....
23	Engine and Round-house Men	10.10	0	0	.....	.....
24	Fuel for Locomotives	10.80	26	45	2.79	4.86
25	Waste, Oil, Water and Supplies, Locomo.	1.36	25	45	0.34	0.61
26	Train Service	5.55	0	0	.....	.....
27	Train Supplies and Expenses	1.91	0	0	.....	.....
28	Switchmen, Flagmen, etc	2.36	0	0	.....	.....
29	Telegraph Expenses	2.44	0	0	.....	.....
30	Station Service and Supplies	5.62	0	0	.....	.....
31	Car Mileage	0.61	0	0	.....	.....
32	Hire of Equipment	0.04	0	0	.....	.....
33	Loss and Damage, etc	1.88	0	0	.....	.....
34	Advertising, Agencies, etc	4.66	0	0	.....	.....
35	Stationery, etc. (Transportation)	0.53	0	0	.....	.....
36	Taxes	5.64	0	0	.....	.....
37	General Expenses	4.38	0	0	.....	.....
	Total, Per Cent.	100.00			3.35	7.13

Tons weight of train, including engine and tender $= \frac{\text{Tractive power}}{6 + 20\ (\%\ \text{grade})}$. In using this formula for estimating the number of trains necessary to handle the tonnage, the weight of freight may be considered as 50% of the weight of train exclusive of the locomotive.

GRADIENTS.—A reduction of gradient on an engine district 100 miles long, so as to require one less daily train in each direction will result in a saving of $37,200 per annum. For other lengths of district, or a greater reduction in the required number of trains, the saving in operating expenses per annum will be in direct proportion to this. Any reduction in length of helper grades, or other change that will eliminate one helper engine of the same size as the standard road engine, will result in a saving of $14,673 per annum, providing the helper engines average 100 miles per day. For other average daily mileage of helper the saving can be estimated as directly proportional to this.

DISTANCE.—A saving in distance will result in the following savings per annum per daily train one way:

Class "A."—Distances so short as not to affect wages of engine or train men, 2.6 cts. per ft., or $137 per mile.

Class "B."—Distances affecting train wages, but not affecting the number of side tracks required, 3.7 cts. per ft., or $196 per mile.

Class "C."—Distances so great as to affect the number of side tracks required, 4.8 cts. per ft., or $252 per mile.

CURVATURE.—The elimination of one degree of curvature will result in a saving per annum per daily train one way: Uncompensated curvature, 23 cts. per degree; compensated curvature, 19⅛ cts. per degree.

RISE AND FALL.—The elimination of one foot rise and fall will result in a saving per annum per daily train one way as follows:

Class "B."—Where grades are such as to require shutting off steam in descending but not to require the application of brakes: On minor grade, 55 cts. per ft.; on ruling grades, 96 cts. per ft.

Class "C."—Where grades are so heavy as to require the application of brakes: On minor grade, $1.15 per ft.; ruling grades, $1.57 per ft.

These values are sufficiently close for the locating engineer to use in comparing the various lines, a final and more careful comparison to be made in the office of the chief engineer.

TABLE 13.—Showing Reduction in Tractive Power of Union Pacific Freight Locomotives, the Tractive Power at 10 Miles Per Hour Being Considered Equal to 1.

Stroke / Drivers.	24" / 56"	28" / 62"	24" / 50"	28" / 56"	30" / 56"
Ratio = S/D	.429	.452	.480	.500	.536
Velocity, M. P. H.					
10	1.000	1.000	1.000	1.000	1.000
11	.988	.970	.988	.984	.982
12	.969	.941	.936	.930	.926
13	.931	.912	.904	.897	.892
14	.903	.883	.873	.867	.860
15	.876	.855	.843	.837	.828
16	.850	.827	.814	.807	.797
17	.825	.802	.787	.778	.766
18	.800	.777	.760	.749	.735
19	.776	.752	.733	.721	.704
20	.752	.728	.708	.693	.673
21	.729	.701	.680	.666	.643
22	.704	.676	.654	.639	.614
23	.680	.652	.629	.614	.589
24	.657	.629	.605	.590	.565
25	.635	.606	.581	.566	.542
26	.613	.584	.559	.545	.522
27	.592	.562	.538	.524	.500
28	.571	.541	.518	.504	.481
29	.552	.523	.499	.486	.463
30	.534	.506	.482	.469	.446

A UNIQUE CASE OF SHORING WORK ON A NEW YORK TELEPHONE BUILDING.

In building construction there is frequently required practical engineering of the highest order—often the invention of novel methods. A case in point is that illustrated herewith, in which a brick and iron building was swung up from overhead rather than shored up from below, in order to remove certain parts of its walls.

In ordinary shoring, in removing walls supporting tiers of beams, the beam-loads, if great, are carried on uprights which must run down to the solid earth. Where loads are light, bearings may be distributed over a large area and a soil foundation does not become necessary. In the present case neither a distribution of bearing nor the ordinary upright support could be applied, on account of the floor loads and the character of the business which had to be carried on continuously in the building. Perhaps no kind of business or building would be encountered by a contractor that would present more difficulties than those met with in a telephone building. The numerous wires entering the cellar of a central station, their running up to the several stories, their distribution close to walls and under the floors to scores of operators, the need of protection from noise, dirt, rain and the usual concomitants of building operations, make an alteration in a telephone central station one of rare difficulty.

The "Madison Square" station of the New York Telephone Co., located at No. 30 East 29th St., New York, N. Y., had become too small for its increasing business, and about a year ago plans were made by the architect, Mr. C. L. W. Eidlitz, of New York, for enlarging the station by building an addition on the lot adjoining to the east. The existing structure was 25 ft. wide and about 80 ft. deep, with three floors above the ground floor, The addition was to be of the same size, and it was desired to unite the two halves into a single building, by removing the east wall of the existing structure. Further, one story was to be added to the height of the building. The work thus involved the problem of supporting the floors of the old building along the east wall while this wall was being removed, and placing suitable columns along this line to carry the floors of the enlarged building.

The difficulties of shoring up the floors in the usual way were soon found to be so great as to make ordinary methods impracticable; and though the plan adopted was much more expensive to the contractors, it was decided upon as the only one at all feasible. Most of the cable-work in the building was carried up along the east wall—the one to be removed—and the main switchboard extended so close to this wall that no room was left for shoring. The work required to be carried on in such a manner as to not interfere with the operation of the exchange. The responsibility for devising a secure method of doing the work fell on the contractors, Messrs. D. C. Weeks & Son.* Mr. F. M. Weeks, the senior member of the firm, proposed the method which was actually employed; the execution was left to the junior member (and general manager) of the firm, Mr. H. T. Weeks.

Advice, for confirmation of the idea, was sought of a number of engineers but from none could a fuller endorsement be had than that it was "a nice scheme and possibly might be safely worked out." It may be stated in advance that the scheme worked to the greatest satisfaction; not the slightest mishap occurred, or the smallest crack during its execution or subsequently from settlement. The building is now about completed

The perspective view, Fig. 1 and the sectional elevation Fig. 2, illustrate the work clearly. Two enormous tripods were used to carry the overhead supports. One tripod was placed on the front area wall, inside and near the line of the wall to be removed, and was 56 ft. 9¼ ins. high measured vertically; the other ran to the bottom of the side wall foundation near the rear end of the wall to be removed, and, including its concrete foundation 2 ft., was within ¼-in of 70 ft. high. With one end bearing on the top of the latter tripod, there were placed transversely over the old building two yellow pine girders, the other end of which was placed on a timber stretcher resting on the west wall, which was not to be disturbed. On the top of these wooden girders, and running longitudinally with the old building and near the inner side of the wall to be removed, were placed the rear ends of two pairs of large I-beams whose front ends rested on the top of the first mentioned tripod. Across these two pairs of I-beams were placed nine pairs of short 8-in. I-beams and on top of these nine pairs of bearing plates. Through these latter ran nine 2-in. wrought iron rods with turnbuckles between all the tiers of beams to be supported; the rods were about 41 ft. 3 ins. long over all. The rods were placed at irregular intervals to make necessary clearances, in some cases down between the closely set chairs of the operator girls. The view, Fig. 3, shows clearly the relation of tripods, I-beam girders and suspension rods. A view from the rear of the new building site is shown in Fig. 4.

Beneath, and crossing each tier of beams, were placed bearing timbers, enough space being left between each beam and timber to take pairs of wooden wedges while underneath the timbers were iron plates on which bore the nuts of the suspension rods.

The turnbuckles, the nuts and the wedges all being in place, the beam ends were loose, leaving the beams still on the wall-plates. One tier at a time, beginning at the top, the floor loads were thrown by the screws on the four great overhead I-beams. The weight of the upper tier having been raised an eighth of an inch, the next lower tier was put on the upper bearing. This caused a deflection of the heavy timber-

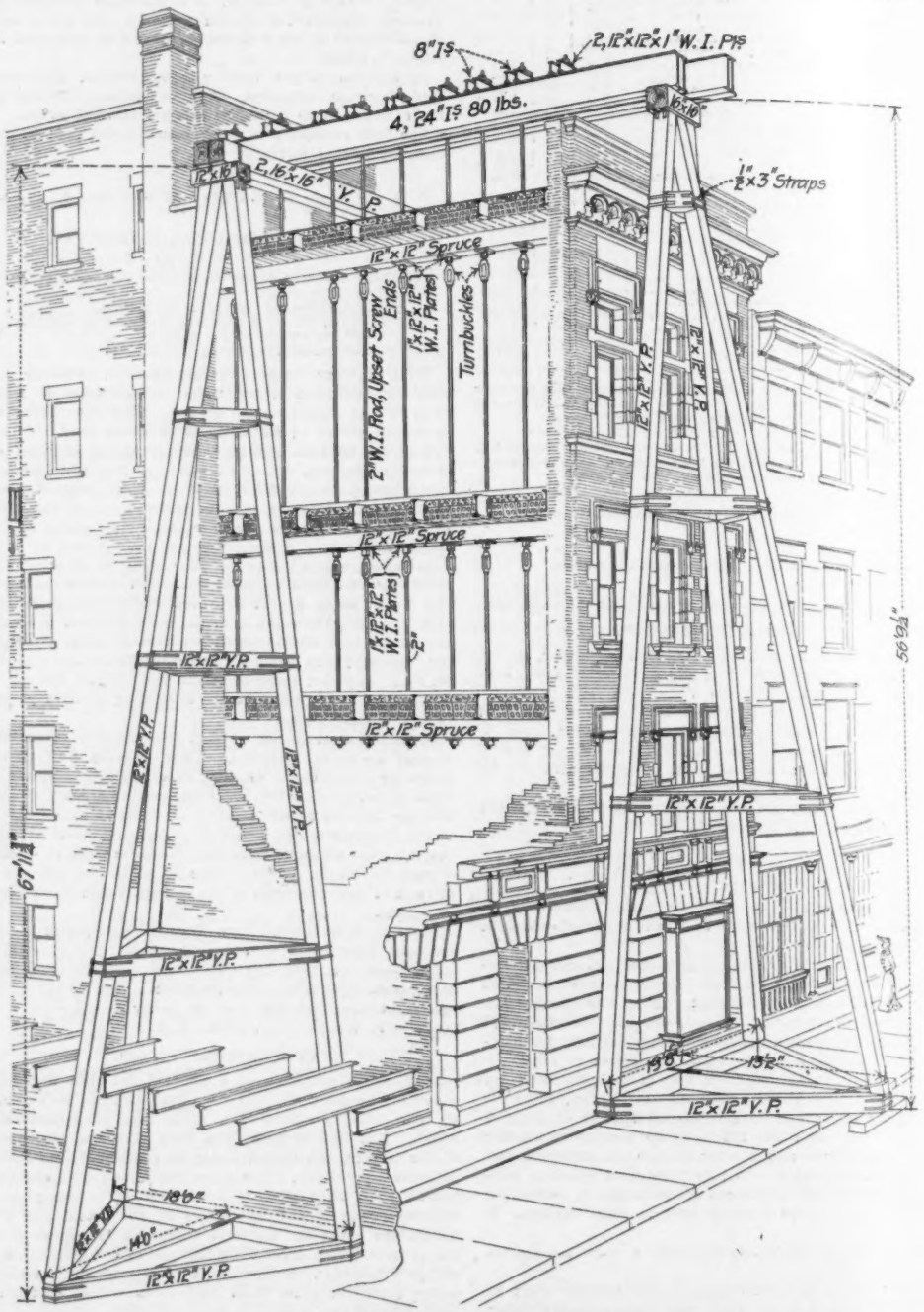


FIG. 1. PERSPECTIVE VIEW OF ARRANGEMENT OF TRIPODS AND GIRDERS FOR SUSPENSION OF MADISON SQUARE EXCHANGE, NEW YORK TELEPHONE CO.

bearing overhead and necessitated the raising of the screws of the upper tier which, having again been cleared from its wall bearings and the second tier being cleared from its bearing, the third was in like manner raised and the upper two adjusted as before. When finally all the weights were thrown on their proper bearing and thus stood, being carefully watched, for a couple of days, the taking down of the wall was started. It may be mentioned that the gradual catching of the beams, as explained, prevented all cracking of ceilings. A leveling board fastened to the ends of the overhead timbers as shown in the photograph, Fig. 5, showed the deflection, which was con-

*This firm, it may be noted, is the oldest concern in building work in New York City, having been established in 1840.

stantly watched. It was found that the two yellow pine girders deflected 1⅛-in., while the four 24-in. I-beams did not appreciably deflect. It was also noted that after the loads were fully caught up there was no further deflection, hence no cracking.

It will be noticed that one of the rods overhangs the cross-support of the 24-in. beams, thereby to a very slight degree cantilevering them and accounting to that extent for there being no deflection in them. But the main reason for this rigidity is seen in the fact that a very large and, as results proved, unnecessary factor of safety, namely 20, was used.

During all the tearing down, most unusual precautions were necessary to secure the building against storms, dirt, etc. The beam ends were then caught up by a girder and columns on the lower tier and girders without columns on the upper tiers and then the shoring appliances were removed inversely as set up.

THE ORIGINATOR OF THE HUDSON RIVER TUNNEL.

A correspondent appeals to us to rescue from the oblivion into which it seems to have fallen, the name of the man who originated the idea of connecting New York City with New Jersey by means of a tunnel under the Hudson River. This man was the late Dewitt C. Haskin, the President and Manager of the Hudson Tunnel Railroad Co. in 1874, and to whom patents were later granted for the method of carrying forward the work by the use of compressed air.

To briefly give the early history of this enterprise, it may be said that in 1874 the above-named company was organized under the general railroad laws of New York and New Jersey, with a capital of $10,000,000. As originally planned—and now practically carried out, the main tunnel under the river was to be 5,500 ft. long, made up of two parallel cylindrical tunnels, each 16½ × 18½ ft. diameter. Actual work upon the New Jersey shaft was commenced in November, 1874, but on Dec. 15, 1874, the work was stopped by an injunction obtained by the Delaware, Lackawanna & Western R. R. Co., and it was not resumed until September, 1879.

On July 21, 1880, a "blow out" occurred at the New Jersey shaft, causing the loss of 20 men by drowning, including Peter Woodhull, the Assistant Superintendent, who heroically lost his life in attempting to save his men. In November, 1882, work upon the tunnel was stopped for lack of funds, with 1,550 ft. of the north tunnel completed and 570 ft. of the south tunnel constructed. The water was permitted to flood the tunnel. Work was again commenced at a somewhat later date and again suspended in September, 1887, with 1,840 ft. from the New Jersey side and 300 ft. from the New York side driven. In 1889 an English company undertook to complete the work. They employed Sir John Fowler and Mr. Benjamin Baker—later, Sir Benjamin—as Consulting Engineers, and let a contract to L. Pearson & Son, the same great English contracting organization which has just received the contract for the East River tunnels of the Pennsylvania R. R. Mr. Haskin was still connected with the work. These engineers substituted a 2½-in. cast-iron shell, 20 ft. in diameter, and a thinner brick lining, for the ¼-in. boiler-plate shell and 24 ins. of brickwork, originally employed. A shield was also now constructed from the plans of Sir Benjamin Baker, was built by Sir Wm. Arrol & Co. at Dalmardock, Scotland, and erected in the tunnel in 1890. About the middle of 1891 work was again stopped on the tunnel from the lack of funds, with about 3,700 ft. of the north tunnel finished; and though a number of attempts were made to reorganize the company, nothing further was accomplished until the present company undertook to complete the work, under Mr. W. G. McAdoo as President, and Charles M. Jacobs as Engineer. At the present date the north tunnel is through from side to side of the river, and work has commenced on the land approaches; the south tunnel has yet to be completed.

Now as to Mr. Haskin's connection with this work: Mr. Haskin is entitled to all the credit for having first promoted this scheme for tunneling the Hudson River, and he devoted sixteen years of his later life to pushing this project toward a successful completion. But he was thirty years ahead of his time, and the failure of his effort was not through any fault of his own. He built enough of the tunnel to show that the scheme was feasible, but the project was of too unprecedented a nature to invite sufficient capital.

Mr. Haskin filed an application for a patent for "an improvement in the construction of tunnels" on Jan. 31, 1883, but he claimed that the invention was older and that he had practically tested his plan in 1880 in the construction of the Hudson River tunnel. And he further claimed that prior to his invention no mode of erecting tunnels in loose mud and sand under the beds of rivers had been known, except "by the use of expensive shields and cofferdams." Though we have no copy of Mr. Haskin's patent at hand, it would seem that he claimed priority for the use of metal plates bolted together so as to form a roof over the advance heading of such a subaqueous tunnel; these plates being in a measure supported and the material held by compressed air. In 1886 he sued parties for infringing upon his patent, but the suit failed for the good reason that similar plates—employed vertically or at an angle, however, instead of horizontally, had long before been used in erecting bridge piers by the pneumatic process, and in 1869 Barlow and Greathead introduced cast-iron rings into the construction of the Tower bridge tunnel under the Thames along with the use of compressed air.

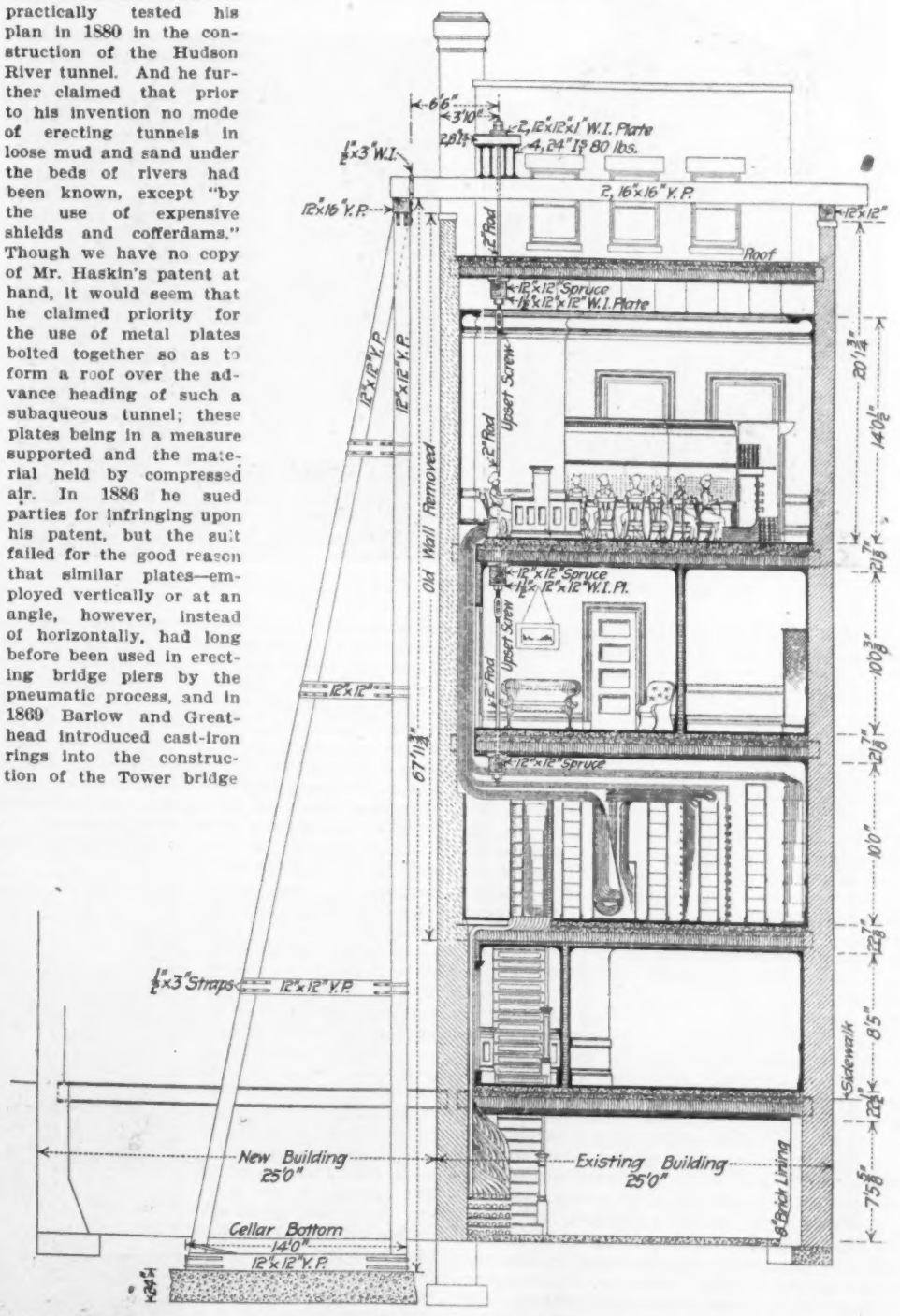


FIG. 2. SECTIONAL ELEVATION OF MADISON SQUARE EXCHANGE, SHOWING SUSPENSION.

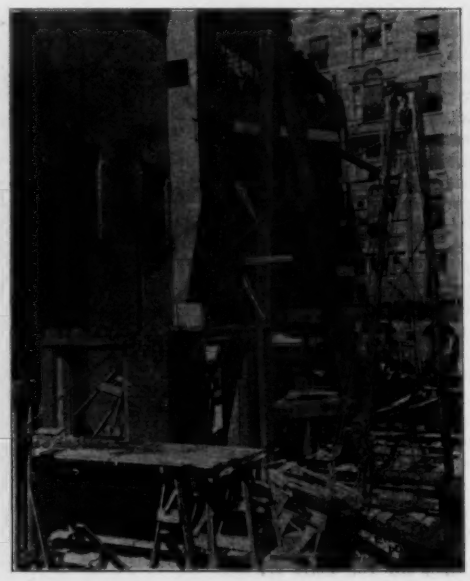
Though the claim has been made for Mr. Haskin, we are certain that he never made any claim for originality in the shield used in the Hudson River tunnel. The shield system of tunneling under rivers was employed by Isambard Brunel in the first Thames tunnel of 1825; in 1863 Peter A. Barlow patented a shield for tunnel construction; and in 1869 Barlow and J. H. Greathead actually used this shield in the construction of the London Tower tunnel under the Thames; and Mr. A. E. Beach built a short section of a tunnel with a shield in New York about 1870. As a matter of fact, the Hudson River shield was designed by Sir Benjamin Baker in 1890, and was similar to one previously used by him on the Humber. Mr. Greathead, of the new Thames and other London tunnels, is entitled to credit for making the shell of the tunnel a continuous series of cast-iron rings; for providing means for injecting cement grout outside the rings, and for other decided improvements in this method of tunneling.

Another name deserving record in connection with the early work on the Hudson River tunnel is that of the late Trenor W. Park, who, with the courage of his convictions and his faith in Mr. Haskin, supplied the bulk of the funds originally expended upon this work. Mr. Park was an eminent lawyer and capitalist who was prominent in the development of California gold mines and later in the building and operation of the Panama R. R., of which he was President until his death in 1882. He is said to have expended nearly two million dollars upon the Hudson Tunnel enterprise.

SOME OF THE REASONS WHY SEPARATORS ARE NOT USED IN PORTLAND CEMENT WORKS.

By Edwin C. Eckel.*

Practically every writer who has discussed the crushing practice at American Portland cement plants, has noted and deplored the absence of separators. In spite of this general unity of opinion on the subject, only a few plants, to the writer's knowledge, are now equipped with any separators; and none have as many as might be used. In view of the fact that American Portland cement practice, so far as crushing methods are concerned, is to-day far ahead of crushing practice in ore-treatment works, this apparent disregard of one great principle of general crushing practice seems to require some explanation. It will not do merely to assume that separators are omitted because the advantages to be gained from their use are not understood by designers and managers of cement plants, for that amounts to charging a peculiarly expert class of mechanical engineers with gross ignorance. In the opinion of the writer, the general omission of separators is entirely justified by certain conditions peculiar to the process of cement manufacture; and the general use of separators would be a serious error in this business. As this opinion may not be generally accepted, and as the grounds on which it is based have never been discussed in print, the advantages and disadvantages of separators may be worth discussing in some detail. This is particularly necessary because the writer realizes, and freely admits that the views which he holds may be proven to be based on incorrect premises. In that case a relatively brief series of experiments which could be carried on in any cement mill, would be of great service to all interested in the technology of the cement industry.



FIGS. 3 AND 4. FRONT AND REAR VIEWS OF SUSPENSION TRIPODS.
(Madison Square Exchange Reconstruction.)

ADVANTAGES OF SEPARATORS.—In crushing any material, if the only things to be arrived at are low cost of crushing per ton of product and high tonnage of product per hour, one fact may be regarded as firmly established. That is, that it is an error to feed to any machine (of the series of reducers employed) material fine enough to go to some machine further along in the reduction process. Beginning with the first or coarsest crusher of the series, while most of its product will only be fine enough to go to the next or second crusher, a certain part of its product will be sufficiently fine to be passed on to the third or even the fourth reducer. If this be done, the product per hour of the series will be greatly increased, each machine will be working on material of fairly uniform size, and the cost of crushing per ton will be greatly reduced.

Applying this to the Portland cement industry, it is probably safe to say that in a series of reducers (consisting, for example, of a coarse crusher, a fine crusher, a Williams or ball mill and tube mills), the product per hour of the series could be increased at least 50% by simply placing separators between each of the steps of the series. The cost of crushing, per ton of product would incidentally be decreased but not in quite the same ratio.

DISADVANTAGES OF SEPARATORS.—In view of the enormous gain in output that would be secured by the use of separation, as noted in the preceding paragraph, it is evident that the disadvantages attending their use must also be very great—for otherwise every cement mill would now be fully equipped with them. The principal disadvantages attending the use of separators, in a Portland cement plant, are two: (1) Separators destroy the uniformity of the product. (2) Separators prevent the attainment of very great fineness. These two objections will be discussed in the order named. It is probable that the second is, in actual practice, the more important.

UNIFORMITY OF PRODUCT DESTROYED BY SEPARATORS.—Throughout the entire course of cement manufacturing processes, from the moment the raw materials enter the mill until the finished cement is packed, the object of the manufacturer is to attain a product as nearly homogeneous as possible. The quality of the cement depends, in large part, on the extent to which his attempts to secure absolute uniformity have been successful. In the opinion of the present writer, one great objection to the introduction of separators into cement practice is that their use will tend to destroy this uniformity.

The action of separators is based commonly on one of two principles. They take advantage either (a) of differences in the weight of particles, or (b) in differences of size of particles. In the first case, the separator, other things being equal, will take out both the finer particles and the particles of lowest specific gravity. In dealing with raw mixtures they will tend to separate the clay particles from the limestone particles. Separators depending for their action on the differences in size between the particles, will take out the finer—which, other things being equal, will, of course, be particles of the constituent which is most readily pulverized. Similar effects will be observed if separators be used in the progress of clinker grinding; for the lighter, more readily ground portions will be separated from the rest; and the uniformity of the product will be destroyed.

GREAT FINENESS PREVENTED BY SEPARATORS.—If, in a plant not using separators, the finest grinders be adjusted to give a product of which 95 per cent. passes a 100-mesh sieve, a very large proportion of that product (say 70 to 75%) will pass a 200-mesh sieve. If separators were installed throughout the plant, and the same adjustment of the fine grinders maintained, a product passing the same 95% through a 100 mesh sieve would probably pass not over 60% through 200 mesh. As it is the percentage of very finely ground particles which gives the chief value to the cement, the use of separators on the clinker grinding side of a cement plant would seem to be inadvisable. In pulverizing raw materials the same objection can be made, though it is not so important as in grinding the finished product.

*U. S. Geological Survey, Washington, D. C.

A SMALL WATER-WORKS SYSTEM AT HENSONVILLE, N. Y.

By E. W. Moxley.*

Hensonville, N. Y., is a pretty village of about fifty families, in the heart of the Catskill Mountains, about seven miles from Hunter. The water-works, which were completed just before the cold weather set in in the fall of 1903, consist of about 5,700 ft. of 6-in. and 1,950 ft. of 4-in. pipe, 15 hydrants and the necessary gate valves.

The distance from the center of village to the reservoir is 4,600 ft. and the difference in elevation is 200 ft. The reservoir is an open one of about 800,000 gallons capacity, and is well supplied with water from several large springs. The springs have been stoned up and the water piped into a catchbasin near the upper end of the reservoir.

From this catchbasin the water is piped to a point below the earth dam which forms the reservoir and delivered into the supply main leading direct to the village. The surplus water is delivered through the upper end of the main pipe into the bottom of the reservoir. The valves are so arranged that all the pipes can be flushed and cleaned and the water drawn from the reservoir without interfering with the supply at the village, the water being drawn direct from the catchbasin which operates as a storage at such times as the reservoir is emptied.

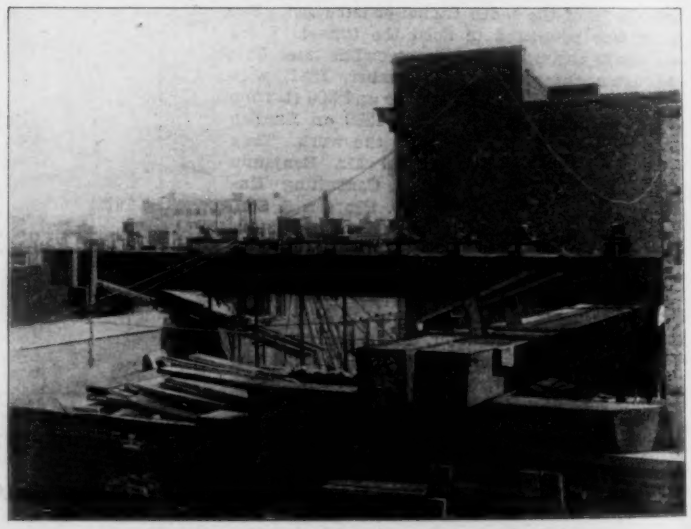


FIG. 5. SUSPENSION GIRDERS AND LEVELING BOARD.
(Madison Square Exchange Reconstruction.)

The works were designed by the writer and were built under his personal supervision, mostly by Italian labor. Construction was begun on Oct. 7 and ended by laying the last pipe on Dec. 9, 1903. The total cost of the plant was about $9,000. The works are owned by a corporation composed of local capitalists.

*Civil Engineer and Surveyor, Jefferson, N. Y.

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